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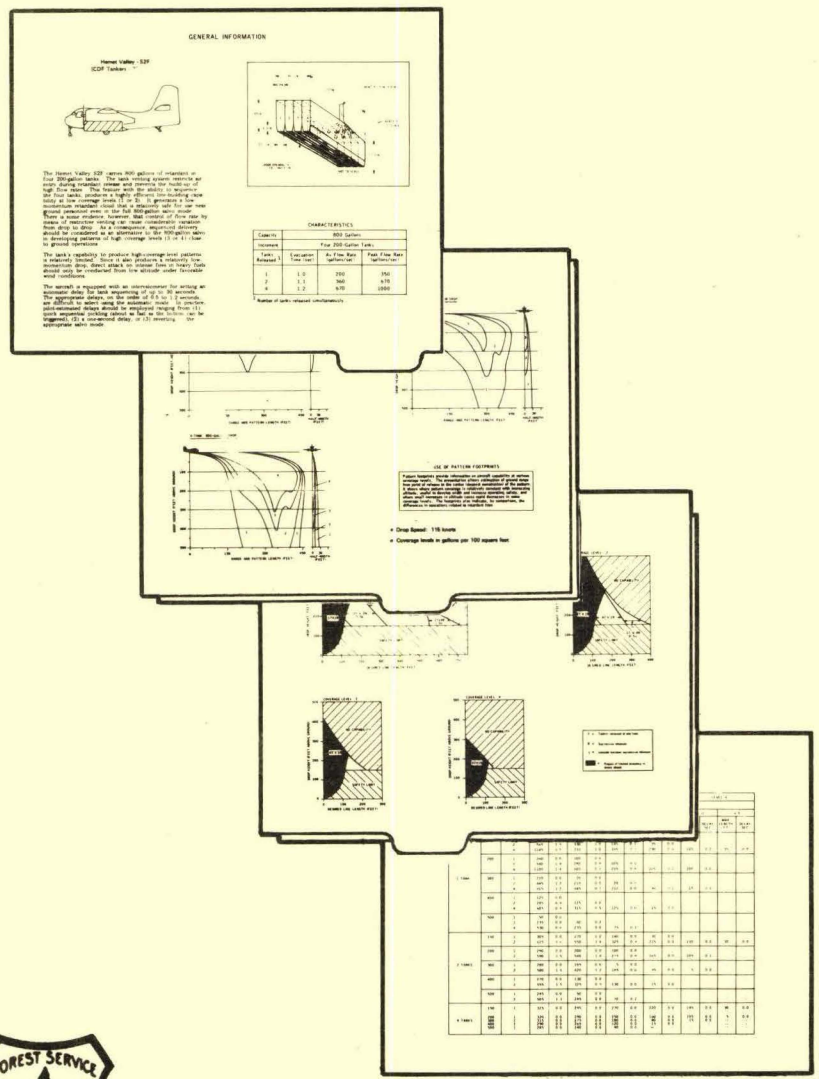

USER GUIDELINES for FIRE RETARDANT AIRCRAFT: GENERAL INSTRUCTION MANUAL

PREPARED BY HONEYWELL INC.
and
THE NORTHERN FOREST FIRE LABORATORY

for

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

A REPORT OF RESEARCH PERFORMED UNDER THE AUSPICES OF THE INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION, OGDEN, UTAH.

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USER GUIDELINES FOR FIRE RETARDANT AIRCRAFT:

GENERAL INSTRUCTION MANUAL

by

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Intermountain Forest and Range Experiment Station
USDA Forest Service
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This manual is published as a part of a program to improve fire control technology, specifically through the use of fire retardant chemicals and delivery systems whose chemical and/or design characteristics are tailored to fuel and fire situation needs. This program is being conducted at the Northern Forest Fire Laboratory. Information or questions regarding these studies should be directed to the:

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Introduction

This Manual, in combination with the various User Guides for individual tanker aircraft, is intended to:

- Introduce a systematic basis for retardant tanker mission planning so that specific airtankers can be employed in the most effective manner based on their inherent capabilities or limitations and the local fire/fuel situation.
- Provide (in association with other guidelines as they are developed) the ability to relate effective performance achieved by one tanker to the inherent capabilities of other tankers that may be brought into the area.
- Introduce a procedure for after-the-fact evaluation of tanker operations so that the most effective retardant drop conditions for the local situation can be identified in a quantitative fashion.

Air tankers differ considerably in their capabilities and limitations because of tank design characteristics, tank sequence options, retardant quantities, and aircraft flight envelopes. When the unique characteristics of an aircraft, in concert with the locally available retardant and usage patterns refined over years of practical experience, are singularly effective in a local fire/fuel situation, that aircraft will become an acknowledged favorite. A different aircraft when asked to perform in the habitual way, may appear totally ineffectual by comparison, even though it too may be a favorite in other regions where different usage patterns, retardants or the like tailor its performance to the particular drop situation.

Recently, considerable advances in the understanding of why tankers perform as they do has been gained in work at the Northern Forest Fire Laboratory. If we know what makes a good drop from one aircraft in a given local situation, we can adjust the usage pattern of a different aircraft to most closely approximate performance of the favored tanker. We can also begin to recognize situational changes from day to day or hour to hour that influence delivery conditions—that change the drops delivered in identical ways from excellent to poor between morning and afternoon.

Despite advances in tanker understanding there are still many unknowns which are related first and foremost to the local fire situation. Perhaps this is as it should be, since broad generalizations often obscure critical issues best comprehended by the personnel with local responsibility. For this reason many of the baseline values issued in these guidelines are suggested points of departure that should be refined based on experience and a certain amount of intelligent experimentation. The guidelines will, if properly used, provide a method of quantitatively assessing the good drops versus the bad drops in postmortems of operations.

For example, if your favorite aircraft is covered by the guides available, think back to a drop that was particularly effective. By estimating drop height at tank release you can determine from the curves presented the pattern value and certain other characteristics of the pattern thus generated. These characteristics, then, provide the critical viewpoint by which we refine our intuition and subsequently attempt to tailor the performance of airtankers for most effective usage. Record keeping is thus encouraged as an integral part of guidelines application.

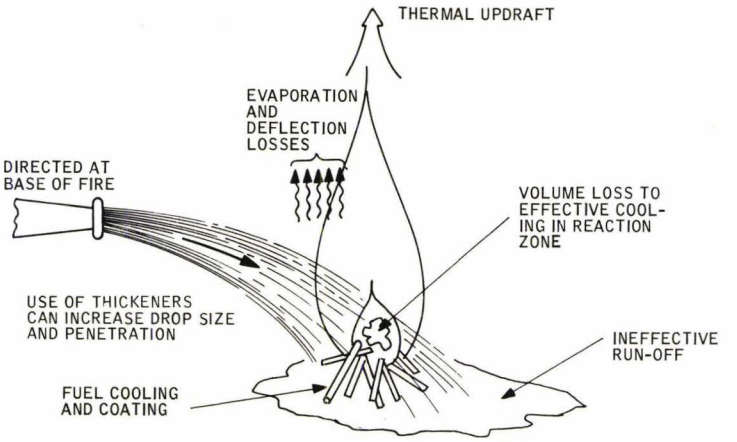
Although experience has been cited above as a method of optimizing usage patterns for the local situation, we do not mean to imply that better ways of using even favorite aircraft cannot be found. Indeed, some of the views presented here may seem inconsistent with your understanding of aerial fire fighting—and they may well be. Nonetheless, our views, intuitions and habits of employing the airtanker have evolved from the water bomber to current retardant aircraft. They are weighted heavily by the preponderance of TBMs and other low-capacity aircraft. They are influenced by our understanding of fire fighting with conventional hoses (and there are both similarities and startling differences). To this extent, current best usage practices of aircraft may be less than optimum. This document then provides, in addition to guidelines, a basis for experimentation, so that even better usage patterns can be identified for more efficient and effective fire management through the use of airtankers.

Conventional Firefighting Has Some Similarities to Airtanker Attack

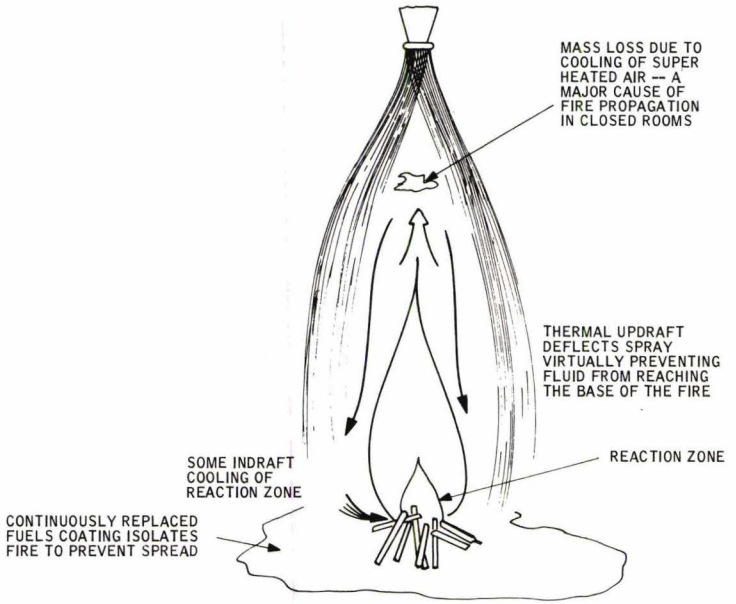
Conventional fire fighting uses the continuous application of retardant or water to drive the fire to total extinction by several means:

- Cooling fuels and gases near the reaction zone.
- Coating fuels surfaces to deprive the surface of heat and oxygen.

Optimized techniques attempt to tailor application rates (gallons/sec) to reduce time of application by minimizing run-off—the amount of material that is not effective in achieving extinction.


THERMAL UPDRAFT
EVAPORATION AND DEFLECTION LOSSES
DIRECTED AT BASE OF FIRE
VOLUME LOSS TO EFFECTIVE COOLING IN REACTION ZONE
USE OF THICKENERS CAN INCREASE DROP SIZE AND PENETRATION
INEFFECTIVE RUN-OFF
FUEL COOLING AND COATING

A Sprinkler System Operates from Above the Fire-Illustrating Both the Problems and Principles of Airtanker Attack


MASS LOSS DUE TO COOLING OF SUPER HEATED AIR -- A MAJOR CAUSE OF FIRE PROPAGATION IN CLOSED ROOMS
THERMAL UPDRAFT DEFLECTS SPRAY VIRTUALLY PREVENTING FLUID FROM REACHING THE BASE OF THE FIRE
REACTION ZONE
SOME INDRAFT COOLING OF REACTION ZONE
CONTINUOUSLY REPLACED FUELS COATING ISOLATES FIRE TO PREVENT SPREAD

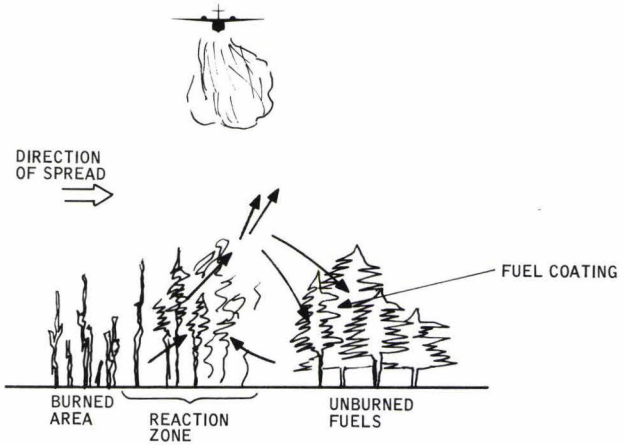
A sprinkler system is not generally credited with the capability of direct suppression since the thermal up-draft protects the flame like an umbrella. Instead it operates against the fire-spread mechanisms by cooling the superheated air and "fire-proofing" adjacent fuels.

Thickeners have been shown to increase drop size, and consequently their penetration into the fire plume.

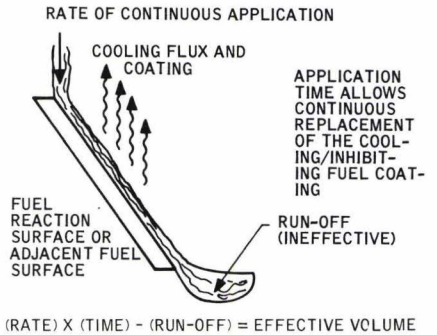
The airtanker attacking the fire from the top is similar in some respects to the sprinkler. The combination of a driving wind and thermal updraft largely deflect drops toward the fuels in front of the fire.

Unlike the sprinkler mass losses taken in cooling superheated air above the fire do little to reduce the spread rate since radiation from the convection column does not contribute significantly to fire spread.

Fuel coating (from water content and thickners), fuel modification (from the retardant salts) and fuel cooling (from the water content) are the major effects achieved in a major fire situation.



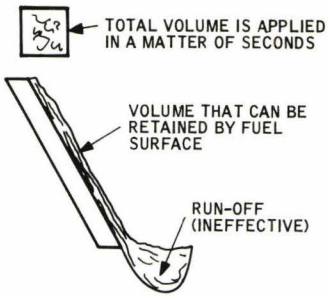
Conventional fire fighting uses time of application to cool or starve the fire to extinction.


RATE OF CONTINUOUS APPLICATION
COOLING FLUX AND COATING
APPLICATION TIME ALLOWS CONTINUOUS REPLACEMENT OF THE COOLING/INHIBITING FUEL COATING
FUEL REACTION SURFACE OR ADJACENT FUEL SURFACE
RUN-OFF (INEFFECTIVE)

(RATE) X (TIME) - (RUN-OFF) = EFFECTIVE VOLUME

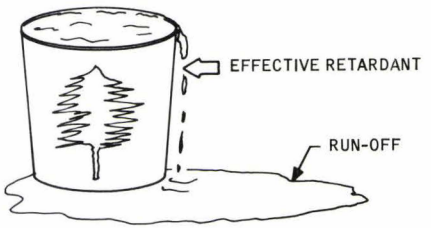
LONG-TERM BENEFITS: The retardant salts continue to alter pyrolysis of combustion mechanisms long after the water content has been dissipated. This effect becomes more significant in aerial retardant delivery than the benefits of fuel cooling and coating from the water content of the fire alone.

Air delivery applies all the retardant at once and must rely on the fuel surface to retain an adequate amount to extinguish, knock down or retard the fire.



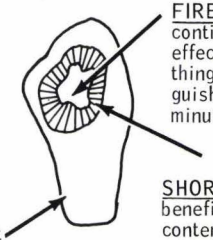
Effective volume is only that which can be retained by the fuel surface. The addition of thickening agents can increase the volume retained on the fuel and slow run-off.

Since the fuel surfaces are limited in the amount of retardant they can retain, any excess application will ultimately be lost ineffectively as run-off.



This factor places practical limits on the useful coverage levels in retardant ground patterns.

It also means that in most cases of direct attack; retardant effects on adjacent fuels are as significant as those on the reaction zone itself.



FIRE: Although dripping and running prolong the continuous effects of the brief application the total effect is limited to what can be achieved in something less than one minute -- few fires are extinguished by conventional techniques in a matter of minutes regardless of application rate.

SHORT-TERM BENEFITS: Limits of the short-term benefits of fuel cooling and coating from the water content of retained retardant. If the effect lasts long enough to resist fire spread to new fuels, delayed extinction will result.

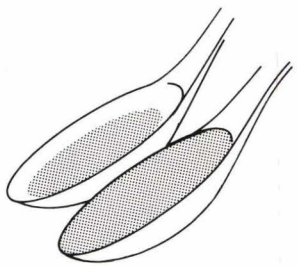
Recommended Coverage Levels

Based on studies of fuel surface capacities, retardant salt effects, moisture damping effects, and experience—knowledge of the pattern capabilities of aircraft known to be effective in certain fuel situations—the following coverage levels can be identified. They are related to fuel models contained in the National Fire Danger Rating System.

Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

For creeping or smouldering fires reduction of one coverage level may be considered.

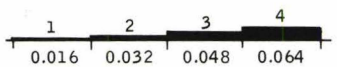
Coverage levels are expressed in gallons per 100 square feet (sometimes abbreviated gpc, gallons per C, the Roman numeral for one hundred). They are derived from the fuel surface area and the effect of retardant salts on spread rate in typical fuels. They are tempered by knowledge gained in experience from the capabilities of aircraft known to be effective in certain fire situations. For example, the Bureau of Land Management has considerable confidence in the use of trail systems against grass fires. Such systems produce considerable line at levels ranging from .5 to 2 gallons per 100 ft^2 and little coverage at higher levels.



ONE GALLON PER 100 SQUARE FEET IS ABOUT 1 1/2 TABLESPOONS SPREAD EVENLY ON THIS PAGE.

EVEN AT HIGHER COVERAGE LEVELS THE AMOUNT IS NOT GREAT -- IT IS EQUIVALENT TO THE DEPTH OF MATERIAL BELOW

OR, EXPRESSED IN INCHES OF RAINFALL

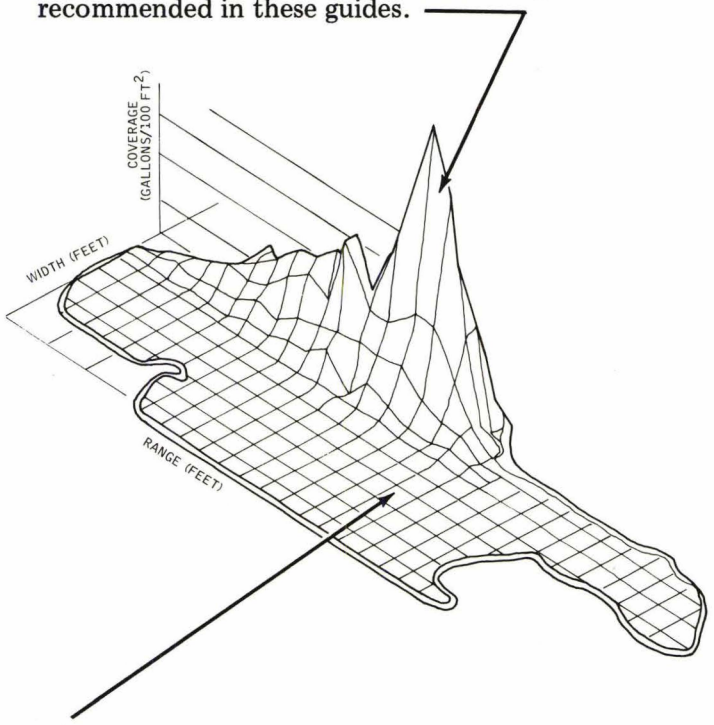


Retardant Patterns

A retardant pattern is an area map of the way the material is distributed on the ground in terms of effective coverage levels. It is a way of representing the characteristic splash pattern of the retardant dumped from an aircraft. It provides a way of evaluating the effects of the drop on the fire/fuels of interest by examining the area, length, and width of the pattern at its various coverage levels.

This three-dimensional representation of the retardant pattern resembles a mountain range emerging from a plateau. It shows how the coverage level, measured in gallons per 100 square feet, fluctuates over the drop area. The coverage level is greatly exaggerated here in the vertical scale.

- The mountain range contains the coverage levels of 1 to 4 recommended in these guides.



- The plateau represents a very low coverage level or trace precipitation, typically about 1/10 of the lowest recommended coverage level.

When presented in terms of an elevation map with lines bounding the areas at or above specific coverage levels, the pattern's effectiveness can be evaluated in various fire situations.

- Considerable areas of the pattern are at coverage levels in excess of that required. They are effective, but the excessive gallonage could be better used if spread over a larger area.
- Some areas are inadequately covered. They have more limited effectiveness and may in many cases be ignored.

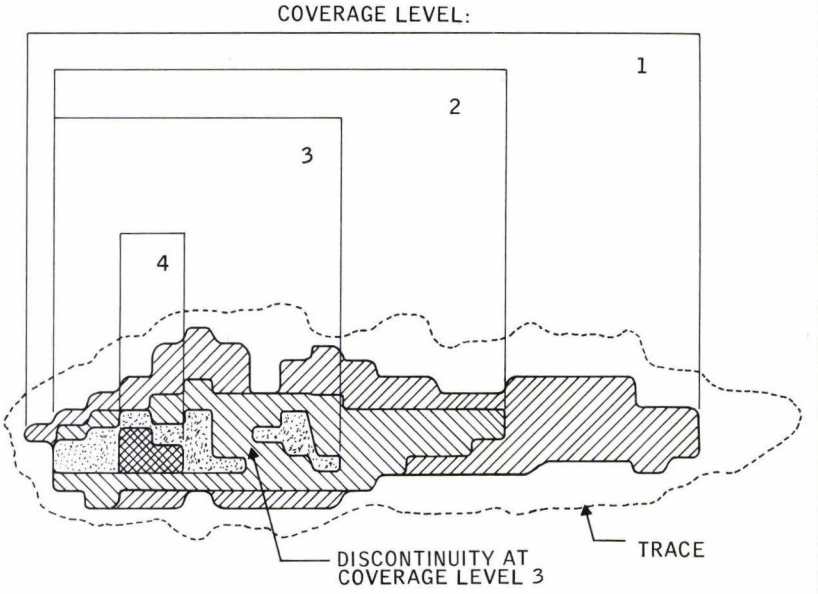
There are three important characteristics of any pattern.

- Length at a given coverage level.
- Width at a given coverage level.
- The momentum of the retardant mass as it falls to the ground.

LENGTH is a direct measure of the line applied in front of the fire. It is also the pattern dimension that accommodates range errors in placing the pattern accurately. Length is controllable by proper selection of the tank release options available to the pilot.

WIDTH is the pattern dimension that accommodates cross-range errors in placing the pattern. Its influence on the fire is difficult to evaluate quantitatively, and it is not generally controllable. Increased width is viewed as a benefit, rather than a dominant variable, in these guidelines.

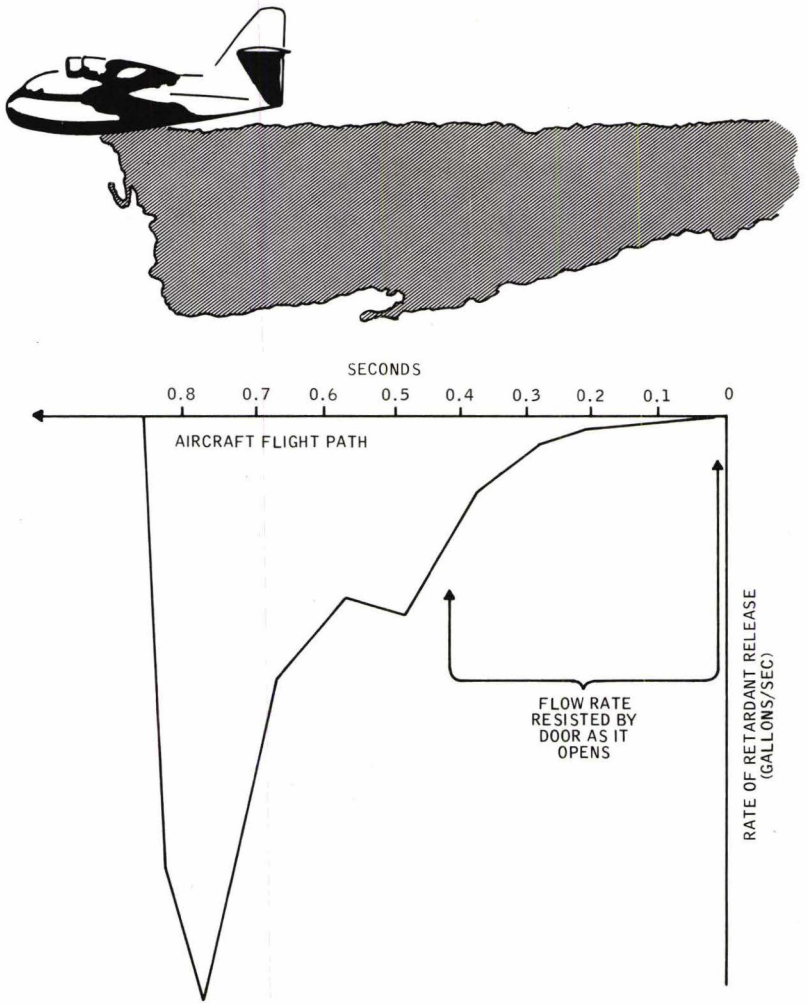
MOMENTUM refers to the velocity and mass of the retardant as it approaches the ground. It determines where the central core of the pattern will land with respect to the drop point. High-momentum drops shoot far down range from the release point, resist wind deflection, and penetrate most fire plumes. They yield small areas at very high coverage levels and have the potential to physically break fuel structures (top trees, etc.). As a consequence they are potentially dangerous to ground personnel. The high-momentum portion of the pattern contributes to accuracy and is usually limited to the lower drop heights.



Volume Flow Rate Establishes Tank and Gating System Performance

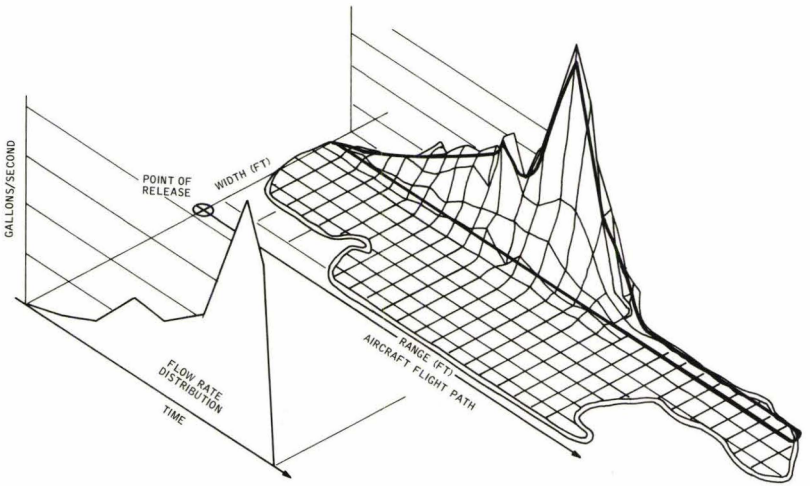
The characteristic volume flow rate from the tank determines pattern performance. Aircraft velocity, altitude, and retardant type, simply modify the recovered values of the retardant distribution achieved on the ground.

The flow rate from the CL-215 for example, has the basic form shown below, which is determined by tank geometry, door opening rate, venting and door area.

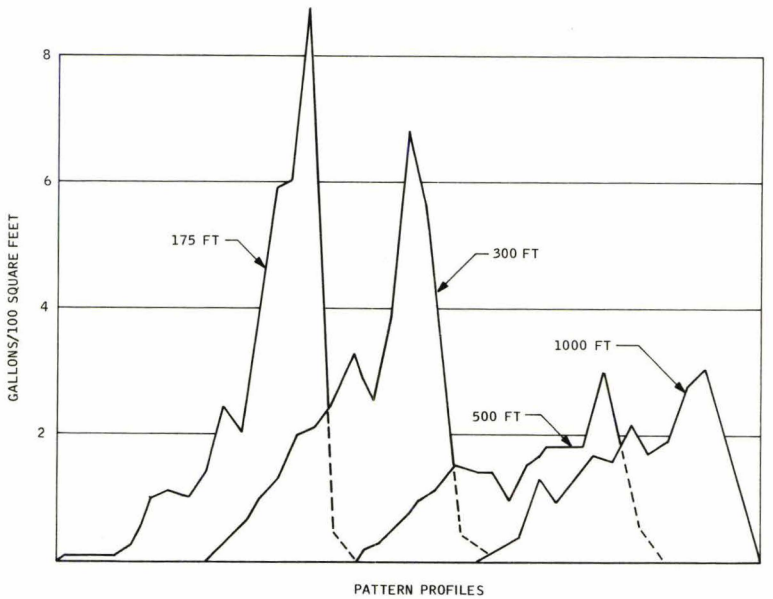


Flow-Rate-Determined Pattern Characteristics Are Visible in Recovered Ground Patterns

The three-dimensional plot below shows how flow-rate distribution is reflected in the ground-coverage pattern.



Flow-determined characteristics are retained regardless of the altitude even though actual coverage levels are reduced as the retardant spreads out in width, and loses material due to evaporation.



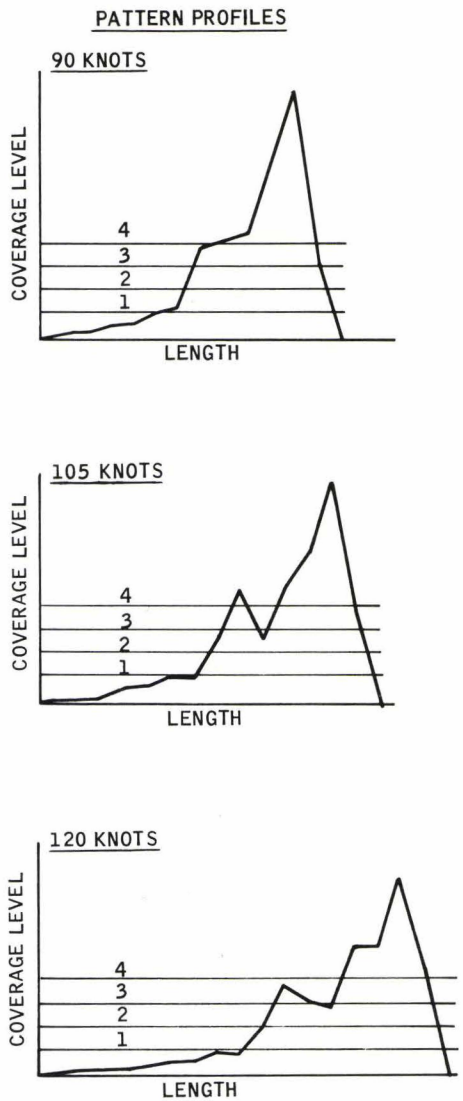
The flow rate from a single tank is fixed by quantity, door-opening rate, tank geometry, venting and door area. The distribution of retardant in the pattern can be controlled to a limited extent by the selection of aircraft drop height, velocity, and angle of attack.

DROP HEIGHT — Increased drop height has the general effect of reducing the peak coverage level and momentum of the pattern, and increasing pattern width. Its effect on pattern length ranges from small to great depending on the particular characteristics of the tank system and the retardant type. Since it affects the pattern, aircraft and ground safety, drop height is a primary variable in these guides.

AIRCRAFT VELOCITY — The aircraft velocity with respect to the ground changes the retardant distribution as shown, but its effect on the coverage levels of interest is not usually as significant as might be supposed. Flying faster will generally reduce peak coverage values, increase pattern momentum, and increase low coverage lengths. All data in these guides are based on the mid-velocity of the specific aircraft.

AIRCRAFT MANEUVER — The effects of dive or toss modes of release are similar to velocity. Diving tends to foreshorten the pattern and increase coverage. The effect is similar to reducing velocity. Toss tends to elongate the pattern. The effect is similar to increasing aircraft velocity. Maneuver selection is more related to the ability to place the pattern accurately than it is to the coverage levels obtained. It is not considered a primary variable in these guides.

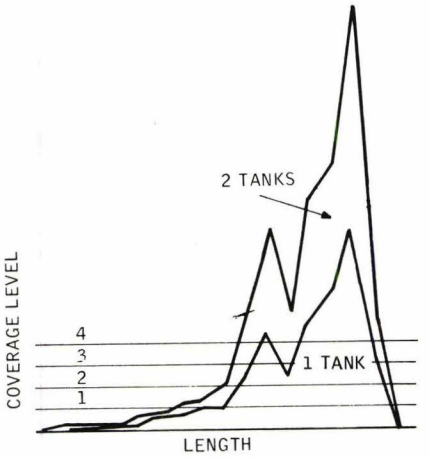
WIND — The effect of wind is to deflect the pattern and greatly increase the pattern's fringe area. It does not generally diminish pattern area or length significantly at the 1- through 4-gallon-per-hundred-square-foot coverage levels. Like drop height, wind will exert a greater influence on water-like retardants, than on gum-thickened products. The smaller drops are more susceptible to drift, deflection, and increased evaporation losses than the larger drops of gum-thickened retardants. Since the effect is more related to placement accuracy than coverage extent, all data in the guides is generated under a theoretical no-wind condition.



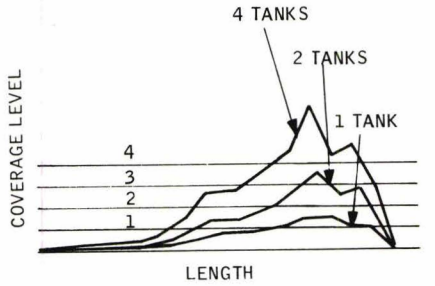
Number of Tanks Determines Aircraft Flexibility

Most aircraft carry at least two tanks, with some containing as many as eight. Considerable control can be exerted on the pattern by the judicious use of the tanking increments available and the time between tank releases.

- Dropping two tanks simultaneously (in salvo) doubles the flow rate and, consequently, the coverage level. It does not necessarily double the length or area at a useful coverage level.

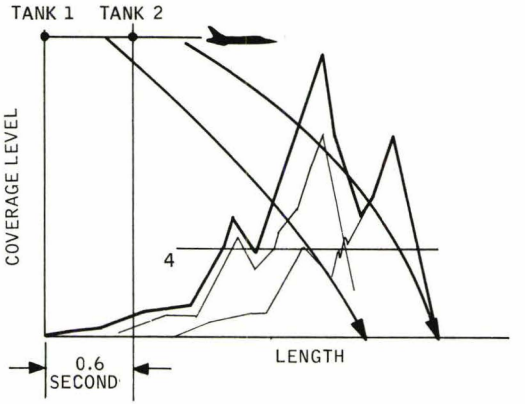


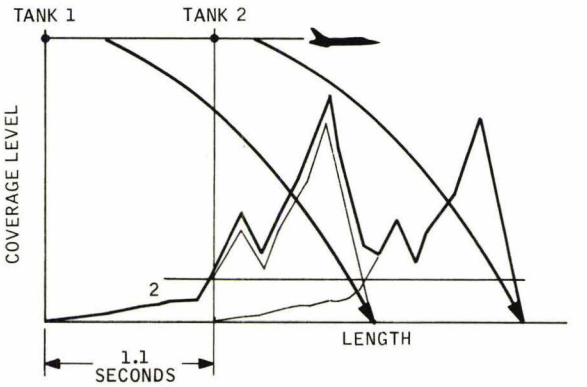
- For some tanking systems, multiple-tank salvos are useful to bring pattern coverage up to the appropriate values: To accommodate the effects of increased altitude or to increase flexibility.



Pattern Can Be Controlled by a Delayed Release Sequence

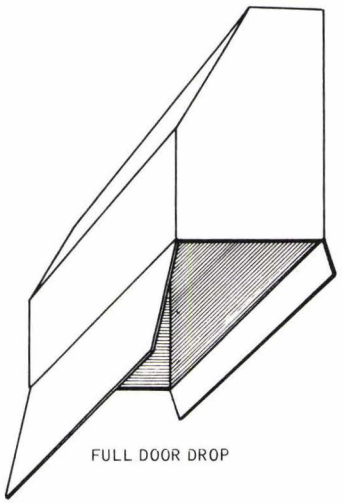
In most cases, the most efficient use of multiple tank drops occurs when individual tank releases are spaced along the aircraft flight path. The appropriate delay interval will vary with drop height, aircraft velocity, retardant type, and the desired coverage level. Few aircraft are equipped to regulate appropriate delays accurately. Nonetheless, delays of the right order can be approximated to maximize pattern length at the required coverage level.



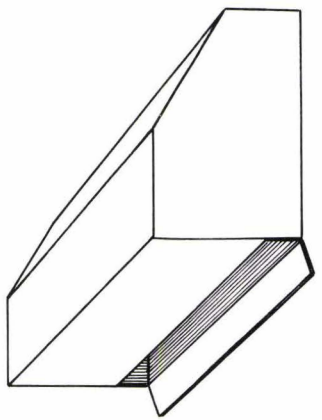


Door Options Can Be Used to Control Flow Rate

Some aircraft offer additional control options by offering a choice of door areas used in the drop. Depending on the desired pattern level either the full door or a door representing some smaller fraction of the tank bottom can be selected.

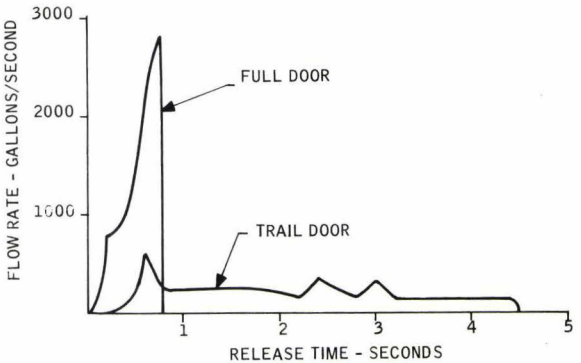


FULL DOOR DROP

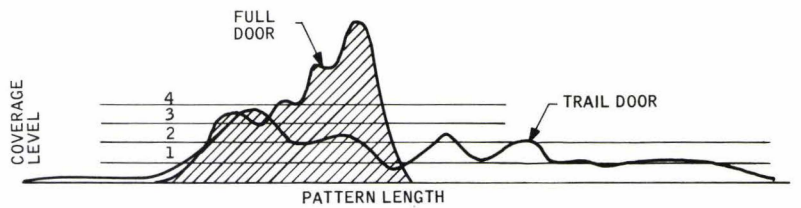


TRAIL DOOR DROP

Flow Rates Available From One Tank With Two Door Options . . . .

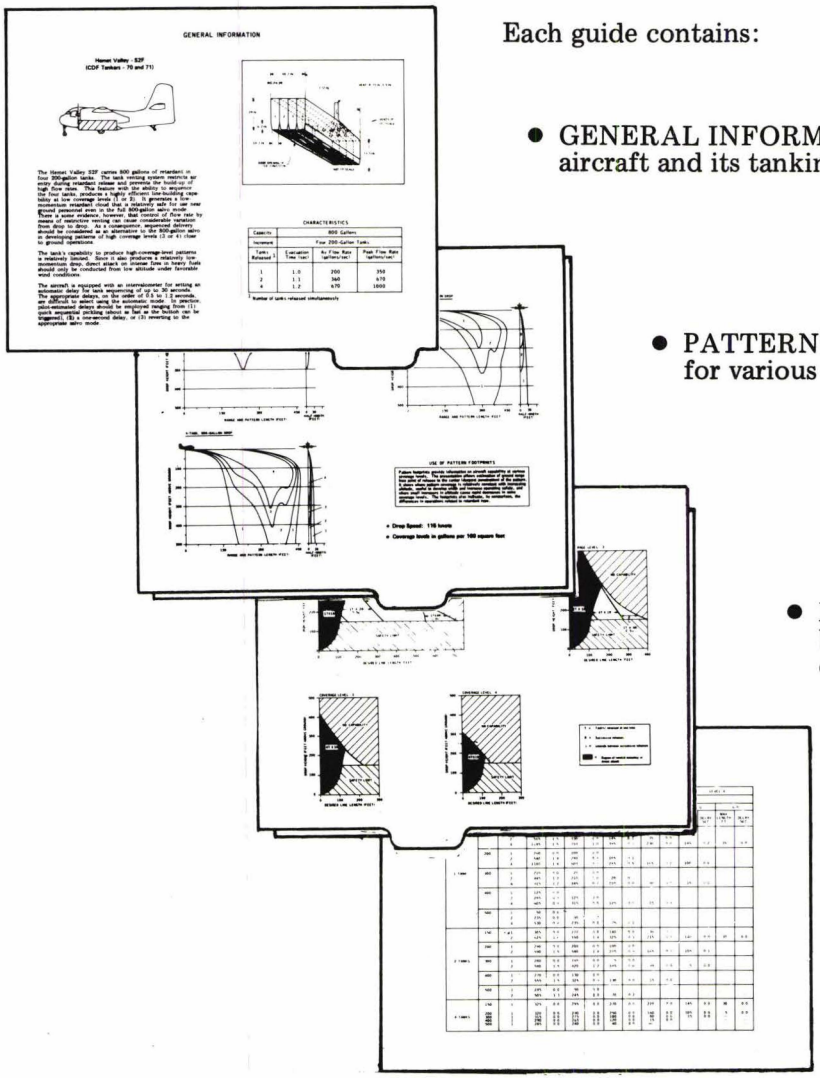


. . . . Yield Two Types Of Ground Pattern



The User Guides are booklets that display data on specific aircraft, in forms useful to the tanker pilot, air attack and ground personnel in achieving the most efficient use of the aircraft.

Each guide contains:

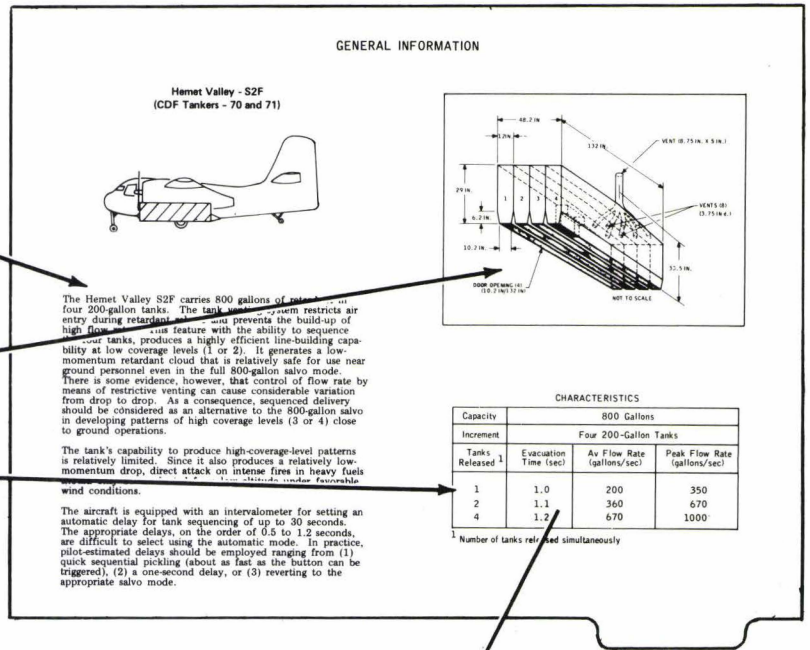


- GENERAL INFORMATION — A brief description of the aircraft and its tanking system
- PATTERN FOOTPRINTS — Plots of pattern coverage levels for various types of drops and retardants.
- BEST STRATEGY CHARTS — Enabling quick selection of the best number and sequence of tanks to be employed for specific coverage requirements and line length.
- DETAILED TABLES — Showing the line length and specific settings for delayed release to achieve maximum coverage at a large number of coverage levels and altitudes

The following pages discuss the use of this information.

The general information section contains three elements:

- A description and assessment of the aircraft tanking system in terms of its limitations and capabilities. It is particularly useful in comparing the aircraft with others that might be used in the region, so that differences in the ways the tankers are employed are generally apparent.
- A schematic drawing of the tank showing the pattern control options available.
- A table of characteristics showing typical tank evacuation times, retardant capacities, and average and peak flow rates.



GENERAL INFORMATION

Hemet Valley - S2F
(CDF Tankers - 70 and 71)

The Hemet Valley S2F carries 800 gallons of [illegible] four 200-gallon tanks. The tank [illegible] system restricts air entry during retardant [illegible] and prevents the build-up of high flow [illegible] This feature with the ability to sequence the four tanks, produces a highly efficient line-building capability at low coverage levels (1 or 2). It generates a low-momentum retardant cloud that is relatively safe for use near ground personnel even in the full 800-gallon salvo mode. There is some evidence, however, that control of flow rate by means of restrictive venting can cause considerable variation from drop to drop. As a consequence, sequenced delivery should be considered as an alternative to the 800-gallon salvo in developing patterns of high coverage levels (3 or 4) close to ground operations.

The tank's capability to produce high-coverage-level patterns is relatively limited. Since it also produces a relatively low-momentum drop, direct attack on intense fires in heavy fuels [illegible] wind conditions.

The aircraft is equipped with an intervalometer for setting an automatic delay for tank sequencing of up to 30 seconds. The appropriate delays, on the order of 0.5 to 1.2 seconds, are difficult to select using the automatic mode. In practice, pilot-estimated delays should be employed ranging from (1) quick sequential pickling (about as fast as the button can be triggered), (2) a one-second delay, or (3) reverting to the appropriate salvo mode.

CHARACTERISTICS

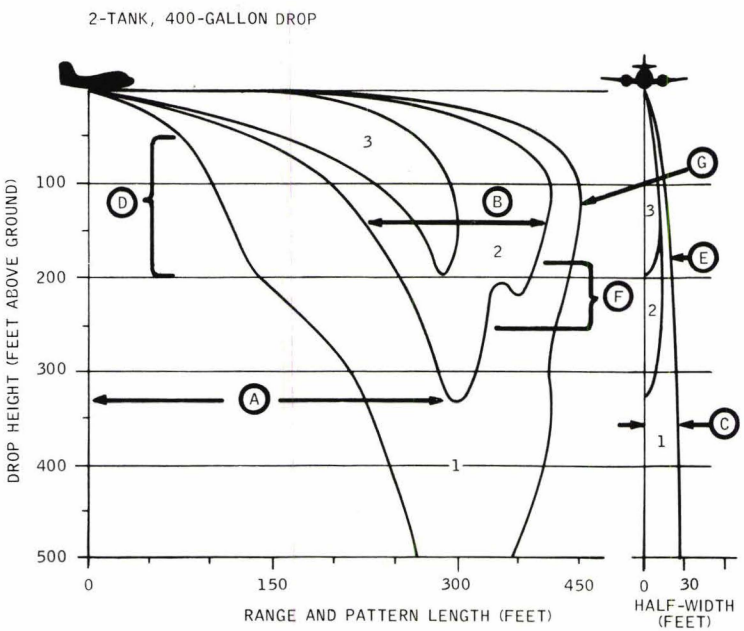
Capacity	800 Gallons		
Increment	Four 200-Gallon Tanks		
Tanks Released [1]	Evacuation Time (sec)	Av Flow Rate (gallons/sec)	Peak Flow Rate (gallons/sec)
1	1.0	200	350
2	1.1	360	670
4	1.2	670	1000

[1] Number of tanks released simultaneously

Using these data, it is possible to compare aircraft quickly. Performance similar to that of a familiar aircraft will generally occur under conditions where the average flow-rates are comparable. For example: A 1000-gallon tank with a 235-gallon-per-second flow-rate is known to produce patterns effective against fires in your region. A new tanker with four 200-gallon tanks becomes available that offers 200-, 400-, and 800-gallon-per-second flow-rate options. Comparable coverage levels (but considerably shorter patterns) will be obtained using the 200-gallon-per-second (single-tank) release under similar delivery conditions. Conversely, if an 800-gallon tank with 1000 gallons per second peak flow has been used effectively in close-support operations, an apparently comparable 750-gallon tank producing a 2000 gallons per second peak flow can be recognized as a potential hazard to ground personnel if flown at the same delivery altitude.

- Average Flow Rate: An indicator of coverage levels generated in the pattern — the lower the value, the lighter the pattern.
- Peak Flow Rate: An indicator of the pattern's momentum. Values much above 1000 gallons per second should be considered as potentially dangerous to ground personnel when released at low altitudes.

Pattern footprints provide information on aircraft capability at various coverage levels over the altitude range. They are generated at the mid-aircraft velocity and show by inspection several important factors of the drop.



(A) Approximate ground range from point-of-release to the center of the pattern, the point of highest concentration. This is useful in estimating the appropriate point of release to place the pattern on spot fires.

(B) The approximate length of the pattern at a given coverage level at the selected drop height. This value can be used in association with observed response of the fire to the drop pattern, to check or refine the recommended coverage level values in specific fire situations.

(C) The effect of altitude on pattern width. Note in this case the maximum area coverage at 1 occurs around 190 feet where the width is greatest just prior to the reduction in length. (E)

(D) Non-critical drop heights. The pattern is relatively insensitive to uncontrolled variables within this range. Small changes of altitude do not cause the pattern to drop below the recommended coverage level. Contrasted to (F)

(F) A critical drop height, where the pattern line (at level 2) falls off rapidly, can become discontinuous, and is sensitive to variables such as wind or drop height.

(G) An indication of the drop height at which the retardant mass loses its forward velocity and falls vertically.

Example-Use of Pattern Footprint to Estimate Effective Coverage Level

A hypothetical 800-gallon drop (A) was made from the Hemet Valley-S2F using Fire-Trol 100 (B) at an estimated drop height of 200 feet. (C)

The lineboss estimated that the drop pattern was significantly effective over not more than 150 feet. (D)

From the footprint, the coverage level appropriate to the specific fire fuel situation can be estimated as shown at right. By comparing the estimated effective length with the coverage level profiles, we can estimate the minimum useful coverage at about 3. (E)

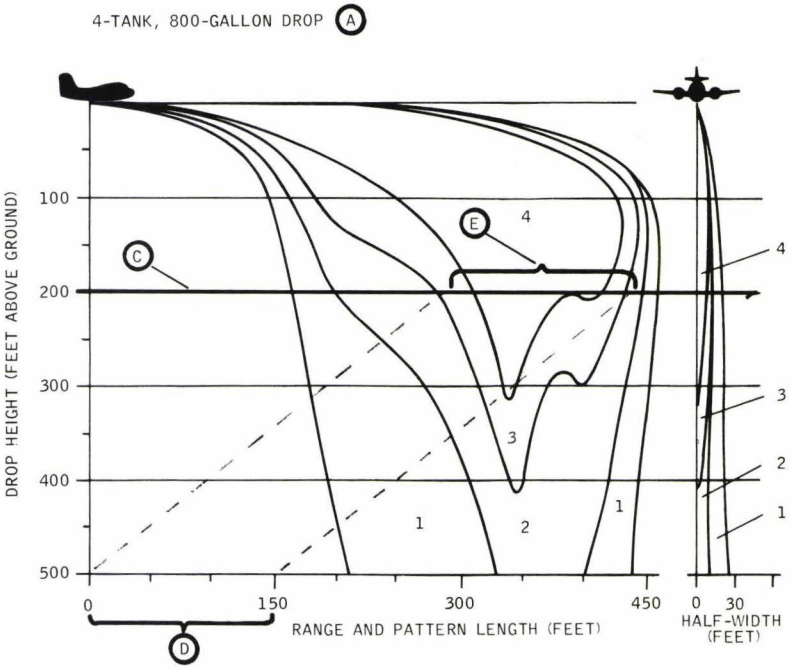
Subsequent evaluation showed the fire was absolutely extinguished for about 50 feet along the flight path.

From the Line Length/Opening Delay tables, the coverage level for extinction can be estimated by examining the estimated lengths at higher coverage associated with the drop. (F)

By this process, in association with intelligent experimentation, it is possible to utilize an aircraft with reasonably well-defined drop characteristics to gather important information on the effect of retardants on actual fires. For this reason, drop post-mortems and data collection are encouraged.

Pattern Coverage Characteristics - WATER-LIKE Retardants

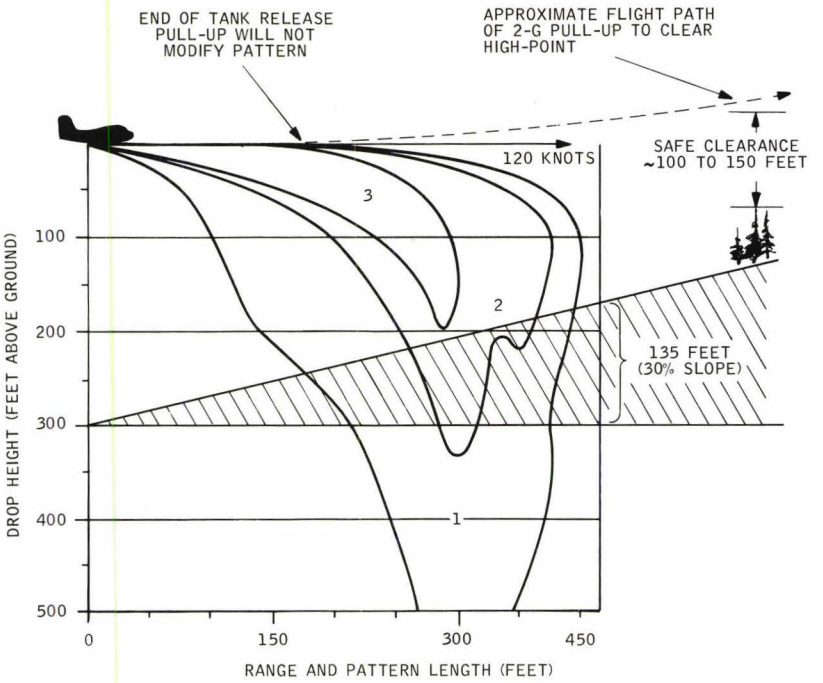
(B) [Fire-Trol 100, Fire-Trol 931 (LC) and Water]



NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	NO. OF PATTERNS	LEVEL 1 COVERAGE 0.5 MAX LENGTH (FT)	LEVEL 1 COVERAGE 0.5 DELAY (SEC)	LEVEL 1 COVERAGE 1.0 MAX LENGTH (FT)	LEVEL 1 COVERAGE 1.0 DELAY (SEC)	LEVEL 2 COVERAGE 2.0 MAX LENGTH (FT)	LEVEL 2 COVERAGE 2.0 DELAY (SEC)	LEVEL 3 COVERAGE 3.0 MAX LENGTH (FT)	LEVEL 3 COVERAGE 3.0 DELAY (SEC)	LEVEL 4 COVERAGE 4.0 MAX LENGTH (FT)	LEVEL 4 COVERAGE 4.0 DELAY (SEC)	LEVEL 4 COVERAGE 6.0 MAX LENGTH (FT)	LEVEL 4 COVERAGE 6.0 DELAY (SEC)
(A) 4 TANKS (C)		2	505	1.3	245	0.0	70	0.2	--	--	--	--	--	--
	150	1	325	0.0	295	0.0	270	0.0	220	0.0	145 (F)	0.0	30	0.0
	200	1	320	0.0	290	0.0	250	0.0	160	0.0	105	0.0	5	0.0
	300	1	315	0.0	275	0.0	180	0.0	80	0.0	15	0.0	--	--
	400	1	290	0.0	265	0.0	120	0.0	15	0.0	--	--	--	--
	500	1	285	0.0	240	0.0	40	0.0	--	--	--	--	--	--

Up-Slope and Down-Slope Drops

The pattern footprints can also be employed to estimate the coverage achievable and approximate release points in terms of altitude and range for drops against severe slopes. In the example at right, a 30% grade is shown as a rise of 135 feet over the 450-foot span of the graph. A straight-edge moved across the footprint at the appropriate angle allows assessment of appropriate release strategy or the ground coverage levels developed. With some additional calculations, the ability of the aircraft to accomplish the drop and to escape safely can be examined under various terrain-clearance conditions.



Best-Strategy Charts

Best Strategy charts summarize the Line Length/Opening Delay tables to allow quick identification of the number of tanks and approximate delays between releases which will achieve the most efficient use of the retardant load for any combination of coverage level, line length, and drop height restrictions. A key to their usage accompanies the charts.

Several important points can be made from inspection of these charts.

First, the selection of a coverage level above what may be necessary can produce a large reduction in efficiency, particularly at low levels. It penalizes aircraft tanking systems with considerable flexibility, if they are asked to perform in a "give me as much as possible" way.

Second, it shows ground personnel and mission planners what can specifically be expected from the aircraft. It allows assessment of whether the use of a full load (drawing maximum line), higher coverages, or multiple drops are more efficient in a given fire attack situation.

Finally they indicate where ground safety or accuracy limits can be anticipated in direct-attack or close-support operations.

Use of Best-Strategy Charts

(A) Select the charts for the retardant type to be employed in the operations. This will be GUM-THICKENED (such as Phos-Chek) or WATER-LIKE (such as Fire-Trol 100).

(B) Select the chart for the appropriate coverage level for fuel and fire situations in the area of operations.

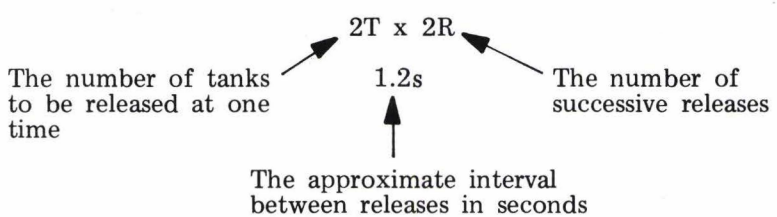
Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

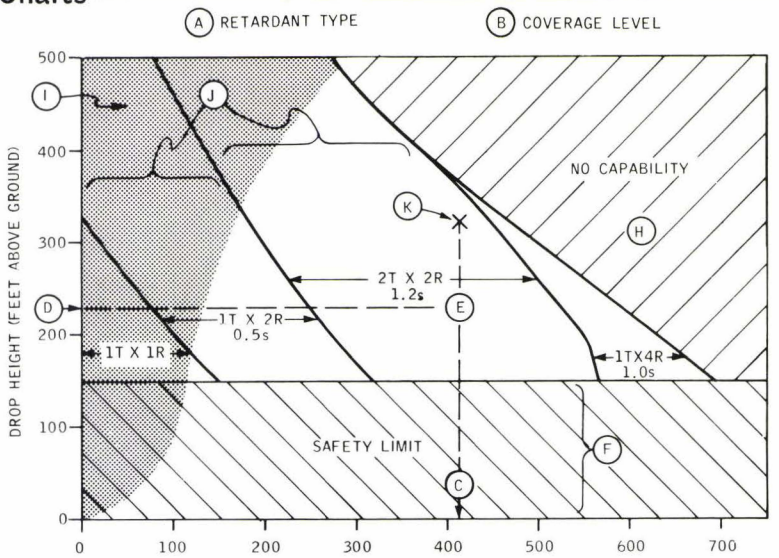
For creeping or smouldering fires reduction of one coverage level may be considered.

(C) Estimate the length of line required for a particular drop at the selected coverage level.

(D) Determine drop-height limits: (1) to assure aircraft safety in clearance of terrain features both before and after the planned release and (2) to protect ground personnel in close-support operations.

(E) Identify the region on the chart defined by the line-length, drop-height condition. This will identify the best release strategy to achieve the required coverage:


2T x 2R
1.2s
The number of tanks to be released at one time
The number of successive releases
The approximate interval between releases in seconds



(G) NOTE: Avoid use of this strategy close to ground operations under 200-300 feet

(F) SAFETY LIMIT -- Usually expressed as a fuel clearance distance; will normally be at 150 feet above ground or greater depending on terrain or fuel features

(G) NOTES -- Indicate recommended altitude limits for high-momentum drops potentially dangerous to ground personnel when used in close support or call out other recommendations or limitations for a particular strategy.

(H) LIMITS OF CAPABILITY -- The aircraft cannot produce, in a single pass, line-length greater than that defined by the limit curve.

(I) REGION OF LIMITED ACCURACY -- The ability to place a pattern of the specified coverage level on a spot fire is doubtful if operations must be conducted in this region.

(J) OPERATING REGIONS -- Most efficient use of the available retardant and pattern controls will occur for the strategy listed. For more precise intervalometer settings see the detailed tables.

(K) If the desired drop is well within the line capability of the release strategy, consider flying higher. This will result in a wider pattern and increased safety.

Maximum Line Length/Tank-Opening Delay Tables

The Maximum-Line-Length tables show, for a selected altitude, the appropriate delay between tank releases to achieve the maximum coverage over a range of potentially desirable coverage levels.

(A) The number of tanks released simultaneously is the basic building block of the pattern. Thus the value 2 indicates a two-tank salvo. The number of patterns (B) tells how many salvos are delivered. The column entries tell the maximum length of line that can be achieved with reasonable certainty at any coverage level as well as the correct interval setting (C) between salvo releases to achieve this value. These delays are far more precise than those presented in the best strategy charts.

Note that intermediate values can be estimated, if desired, by interpolation between points listed.

(A) NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	(B) NO. OF PATTERNS	LEVEL 1 COVERAGE (GALLONS/100 FT^2) 0.5 MAX LENGTH (FT)	0.5 DELAY (SEC)	1.0 MAX LENGTH (FT)	1.0 DELAY (SEC) (C)	LEVEL 2 2.0 MAX LENGTH (FT)	2.0 DELAY (SEC)	LEVEL 3 3.0 MAX LENGTH (FT)	3.0 DELAY (SEC)	LEVEL 4 4.0 MAX LENGTH (FT)	4.0 DELAY (SEC)	6.0 MAX LENGTH (FT)	6.0 DELAY (SEC)
	150	1	275	0.0	140	0.0	--	--	--	--	--	--	--	--
		2	565	1.5	330	1.0	145	0.1	35	0.0	--	--	--	--
		4	1145	1.5	710	1.0	395	0.7	230	0.0	145	0.2	35	0.0

Comparison of Retardant Capabilities

All data in the guidelines is presented for two different types of retardant compositions. The distinction is based on the type of thickening agent which causes considerable performance differences in the way the retardant breaks up and survives over the altitude range. The two types are identified as:

- Gum-thickened - including Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)
- Water-like - including Fire-Trol 100, Fire-Trol 931 (LC) and water

The categories refer to rheological properties that influence the breakup in the airstream, not to their effects in coating the fuels or controlling the fire. Indeed, the evidence suggests that their operations on the fuels are nearly equivalent.

The advantage of the gum-thickened retardant appears to reside in its tendency to break into larger droplets, providing less surface area to evaporation effects, and a higher drop momentum that resists wind deflection. This is shown by comparing the pattern footprints on the following two pages.

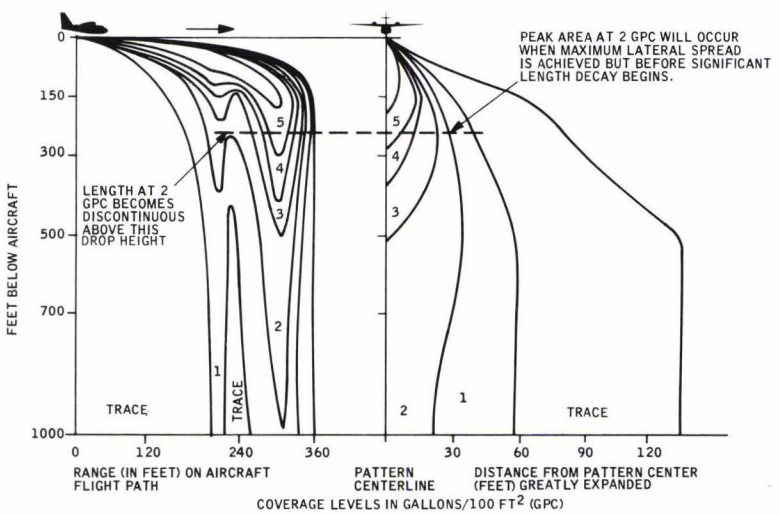
That the two types of retardant are equivalent in other respects is supported by the following evidence:

- Fuel Surface Coating: Although clay-thickened retardants produce relatively thicker coatings than gum-thickened retardants in dip tests (static conditions), they appear to produce thinner coatings when splashed against the fuel surface (dynamic conditions). Since both conditions contribute to actual fuel coating, the differences might well be offsetting. Observations in the field tend to support this contention in that it is difficult to tell the difference between retardant compositions by the fuels coverage in areas of similar concentration.

- Retardant Effects on the Fire: The active salts of commonly used retardants produce differing effects on certain fires. In terms of the effect on spread rates, which is critical to most air-delivery missions, the salt concentration is set to produce essentially equivalent effectiveness. Indeed the differences are sufficiently minor that a single value of Maximum Useful Concentration closely defines both commonly used retardant effects (reference: Rothermel, R.C., and Philpot C.W., "Reducing Fire Spread in Wildland Fuels," Northern Forest Fire Laboratory, Missoula, Mont. July 9, 1974).

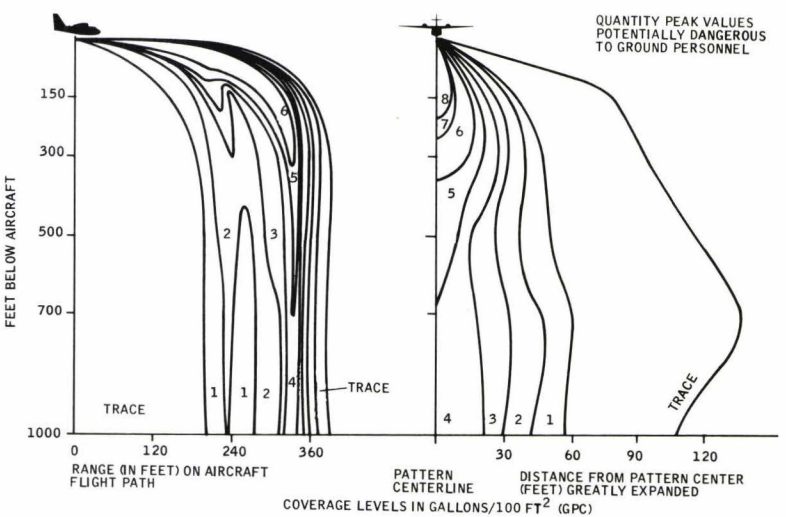
Altitude Effects on Water-Like Retardants

The accompanying graphs show the depth of altitude survival for various coverage levels in a single-tank drop of waterlike retardants. They provide an indication of the achievable length of line at any given coverage level. Note that the pattern width tends to increase as the retardant falls, until the processes of pattern decay (evaporation losses and over-spread) began to offset the advantages of increasing width. This process yields maximum area coverage at delivery altitudes that are often higher than the lowest safe delivery. In this case the maximum area above 2 gpc would be expected to occur at about 230 feet.



Altitude Effects on Gum-Thickened Retardants

Phos-Chek XA exhibits the altitude performance conditions shown in the accompanying graphs. The pattern retains its coherency over a far greater altitude range than for water-like retardants. This is caused by the formation of larger, more uniform drops that lose less due to evaporation and diffusion as the pattern spreads. In this example, the pattern width reaches a peak at around 250 feet which also corresponds to the maximum length value.



For a retardant pattern to be effective, we must place it where we want it on the ground. This implies that there is an aimpoint--some landmark or feature that can be recognized as a target. Some targets are precisely defined--such as the origin of smoke or flame of a spot fire or the reddened fuels of a prior line-drop that must be tied in. Others are not points of reference, but objectives--across the right flank of the fire. In this case some arbitrary aimpoint must be assumed as the reference for placing the drop. The position of the aimpoint is not the only uncertainty in achieving pattern placement. Others include:

- Systemic Uncertainties
  - Ground speed
  - Altitude
  - Aiming error
  - Pilot reaction time
  - True line of flight.
- Tank and Retardant Uncertainties
  - Trajectory variability
  - Ballistic errors
  - Wind
  - Equipment response time.

Values of these uncertainties, taken from known data or estimates, are tabulated in an error budget.

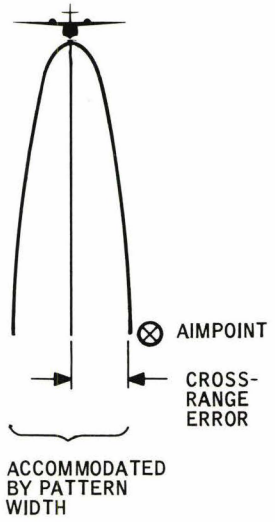
It is convenient to identify these uncertainties into two effects on placement accuracy:

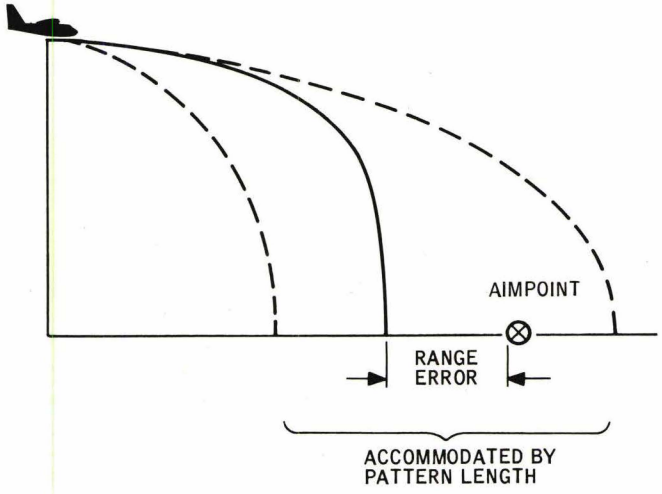
1. Cross-Range Errors - Related to the distance the pattern is left or right of the aimpoint.

2. Range Errors - Related to the time of release and aircraft position with respect to the aimpoint along the flight path. It is the distance the pattern is up or down-range from the aimpoint.

Range Errors are the largest source of accuracy problems identified in the error budget. They are also the most easily overcome; i.e., we can, within limits of the tanking system, generate longer patterns to accommodate range errors.

Cross-Range Errors are smaller than range errors, but we can do little to correct them by manipulation of tanking options. Although the width of the pattern generally increases with altitude, it does not increase as fast as the cross-range error.



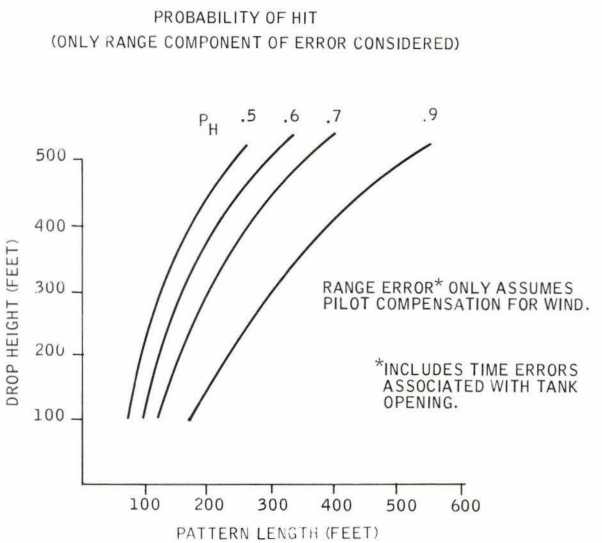


Generalized Probability of Hit

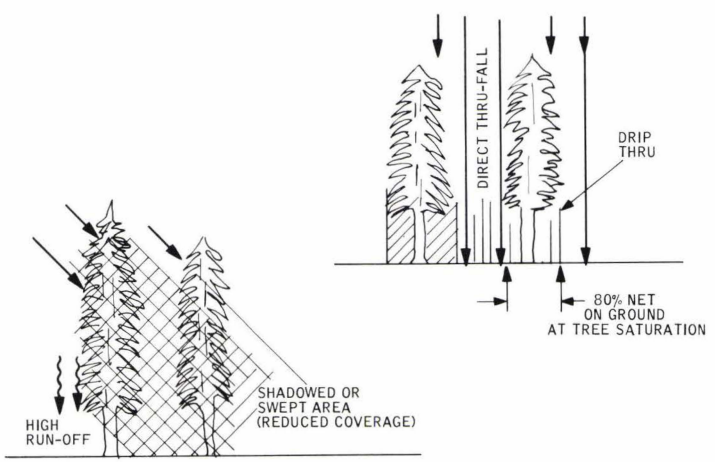
The accuracy of a given drop is both a function of the pilot's skill, unique characteristics of the aircraft, and the circumstances related to the drop. Therefore it is not practical to give fully prescriptive guidelines on accurate delivery. One feature of aircraft tanking systems, however, is their ability to accommodate range errors by increasing line length proportionately. This requires, of course, that the pilot commence his drop early and prolong the line beyond the estimated point of release to hit the intended aimpoint.

The figure shows the effect on probability of hit of generating longer line lengths under good (low-wind) delivery conditions. The value for a probability of hit of 60 percent is used on the Best Strategy charts to define the region of limited accuracy.

Three points are significant in controlling accuracy. First, it is best, where possible, to fly so that uncertainties are predominantly in range where increased length can overcome them--such as flying with the wind (or against it) versus on a cross-wind course. Second, it is more efficient to build the longest continuous line at adequate coverage level from a single aircraft pass than to attempt to connect patterns from separate deliveries. Third, since delivery accuracy is to a great extent dependent on pilot skill, the ability to place the pattern will be enhanced if similar retardant and drop missions are used repeatedly, allowing the pilot to develop experience in judging his drop trajectory.



Notes on Coverage of Ground Fuels



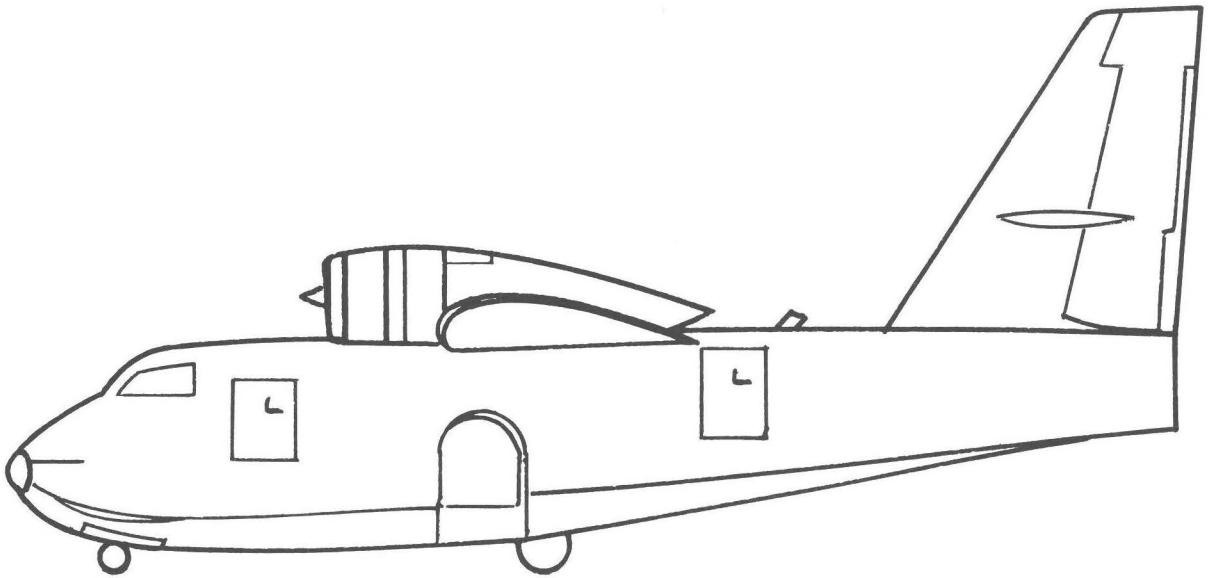
Two basic options for achieving adequate coverage of ground fuels beneath an overstory can be employed. They are:

- Delivery in horizontal flight from relatively high altitudes which takes advantage of the vertical openness of most stands.
- Attempts to drive the retardant through the overstory by low-level or dive attack.

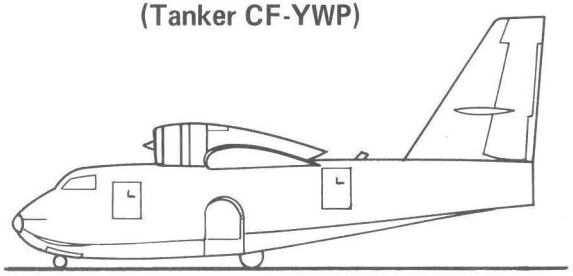
Use of the near-vertical fall of the retardant can be shown, in most cases, to yield the most uniform and consequently most efficient retardant distribution which maximizes direct thru-fall of open areas as opposed to the shielding of certain areas as the angle of entry is increased. Drip-thru as the vertical fuel discards excess retardant, prolongs the application time (on the order of 10 minutes) which can be a benefit.

Canadair CL-215

RETARDANT DROP USER GUIDE
for
CANADAIR CL-215 AIRCRAFT
(TANKER CF-YWP)



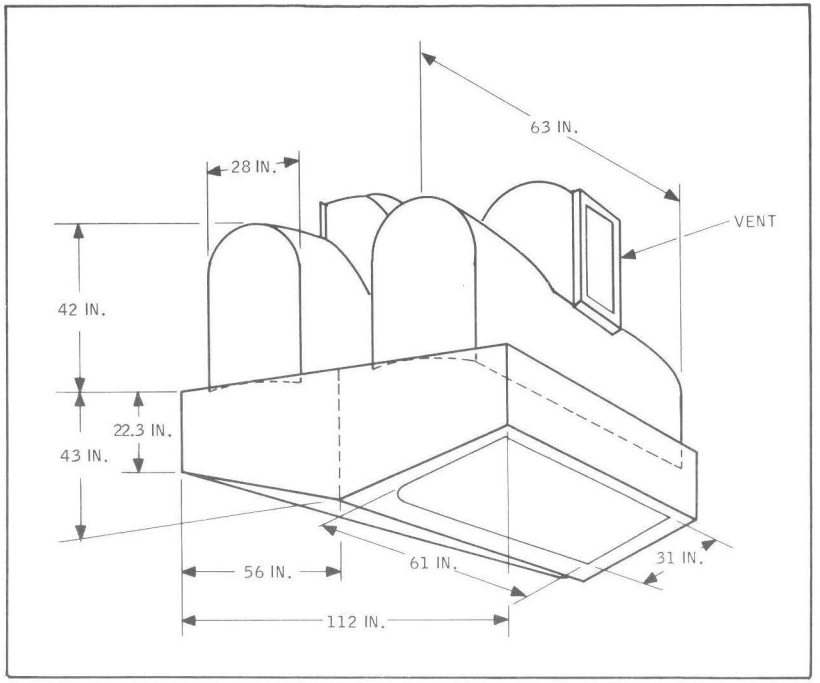
Canadair CL-215
(Tanker CF-YWP)



The Canadair CL-215 is equipped with two 700-gallon-capacity tanks. Large, exceedingly rapid, gravity-drop doors, and thoroughly adequate venting enable the aircraft to deliver exceptionally heavy retardant ground patterns. This characteristic, and its ability to scoop-fill the tanks with water when lakes are available, make the CL-215 uniquely suited to direct attack on small fires where manned follow-up is impractical. It lacks any design features to spread retardant and is somewhat inefficient in generating line or providing the uniform patterns associated with recommended retardant coverage levels. Since the single-tank release produces a retardant mass with considerable momentum, it has the capability to physically break vertical fuel structures (top trees, etc.). As a result, considerable care should be used in any drops close to ground operations. The two-tank (1400-gallon) salvo should not be employed, and the single tank drop should be avoided at drop heights of less than 200 feet.

The aircraft has no intervalometer to sequence the release of its two tanks. Best coverage at retardant levels of 1 or 2 will occur with a pilot-estimated 1-second delay between tank releases. This delay should be estimated on the short side to assure continuity of the line. For higher coverage levels, a delay of ½ second is appropriate--about the fastest rate at which the pilot can pickle the two tanks separately. Although the difference between pilot sequencing and the full two-tank salvo would appear minor, the results--better than 50% more line--are significant.

Another unique characteristic of the CL-215 when used to deliver a gum-thickened retardant is that most efficient low-level coverage (1 or 2) occurs when the aircraft flies at 250 to 300 feet above the ground. The additional drop height gives the retardant time to spread, producing a larger more uniform drop pattern. (This is not a characteristic of water-like retardants, where a faster spreading process and greater evaporation loss rate offset the potential gain.)



CHARACTERISTICS

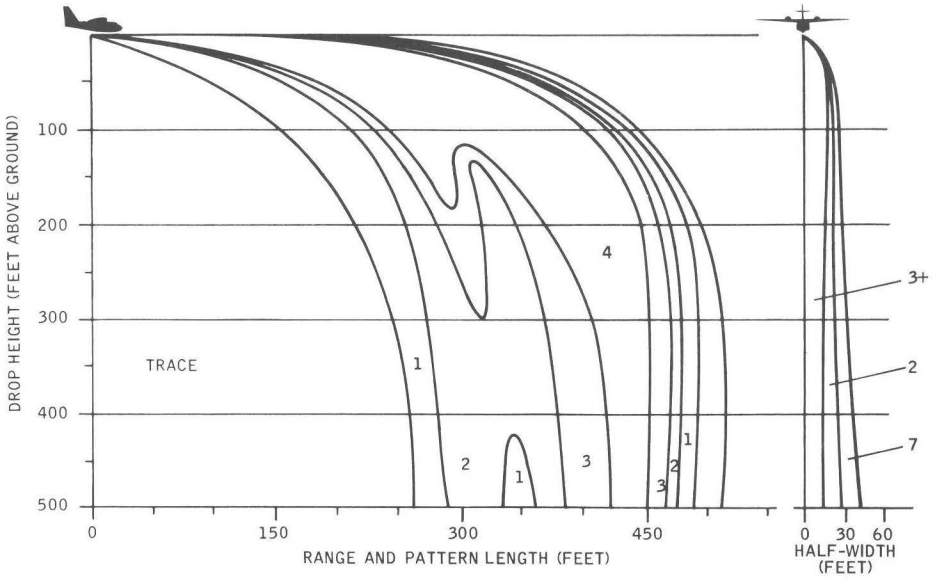
Capacity	1400 Gallons		
Increment	Two 700-Gallon Tanks		
Tanks Released [1]	Evacuation Time (sec)	Av Flow Rate (gallons/sec)	Peak Flow Rate (gallons/sec)
1	0.7	1000	2000
2	0.7	2000	3980

[1] Number of tanks released simultaneously

Pattern Coverage Characteristics - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

1-TANK, 700-GALLON DROP

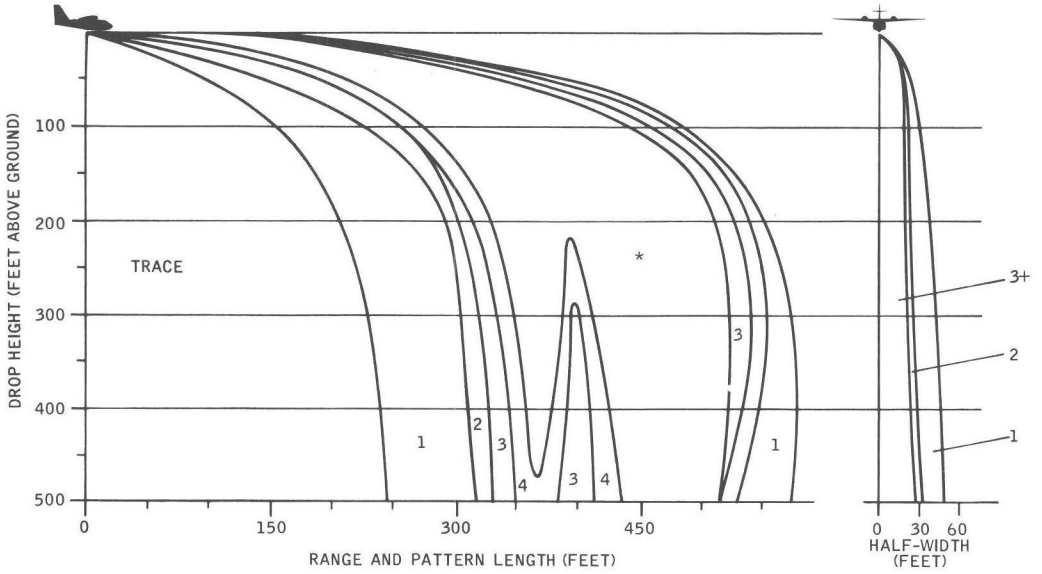


Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

For creeping or smouldering fires reduction of one coverage level may be considered.

- Drop Speed: 105 knots
- Coverage levels in gallons per 100 square feet

2-TANK, 1400-GALLON DROP



*Indicates coverage levels considerably above 5 gal/100 ft^2

CL-215 (3)

USE OF THE BEST-STRATEGY CHARTS

(A) Select the charts for the retardant type to be employed in the operations. This will be GUM-THICKENED (such as Phos-Chek) or WATER-LIKE (such as Fire-Trol 100).

(B) Select the chart for the appropriate coverage level for fuel and fire situations in the area of operations.

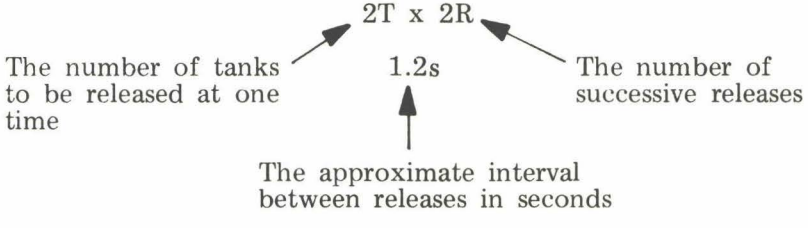
Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

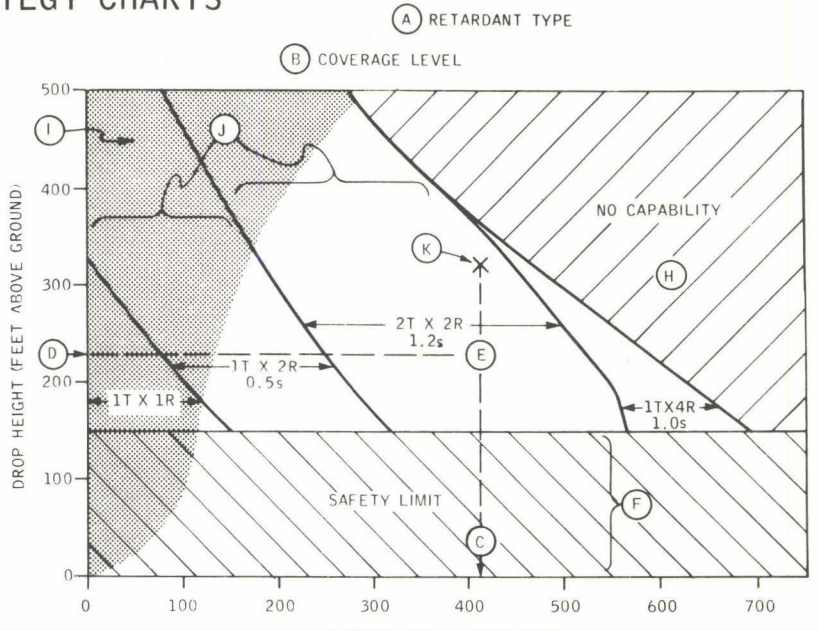
For creeping or smouldering fires reduction of one coverage level may be considered.

(C) Estimate the length of line required for a particular drop at the selected coverage level.

(D) Determine drop-height limits: (1) to assure aircraft safety in clearance of terrain features both before and after the planned release and (2) to protect ground personnel in close-support operations.

(E) Identify the region on the chart defined by the line-length, drop-height condition. This will identify the best release strategy to achieve the required coverage:


2T x 2R
1.2s
The number of tanks to be released at one time
The number of successive releases
The approximate interval between releases in seconds



(G) NOTE: Avoid use of this strategy close to ground operations under 200-300 feet

(F) SAFETY LIMIT -- Usually expressed as a fuel clearance distance; will normally be at 150 feet above ground or greater depending on terrain or fuel features

(G) NOTES -- Indicate recommended altitude limits for high-momentum drops potentially dangerous to ground personnel when used in close support or call out other recommendations or limitations for a particular strategy.

(H) LIMITS OF CAPABILITY -- The aircraft cannot produce, in a single pass, line-length greater than that defined by the limit curve.

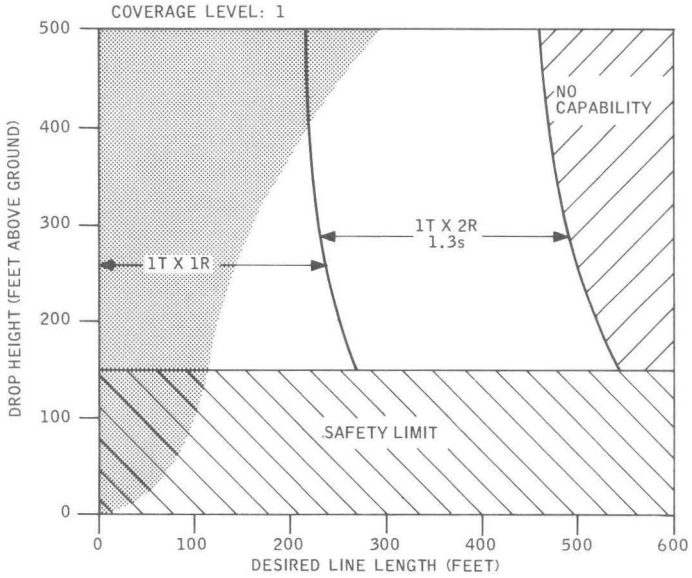
(I) REGION OF LIMITED ACCURACY -- The ability to place a pattern of the specified coverage level on a spot fire is doubtful if operations must be conducted in this region.

(J) OPERATING REGIONS -- Most efficient use of the available retardant and pattern controls will occur for the strategy listed. For more precise intervalometer settings see the detailed tables.

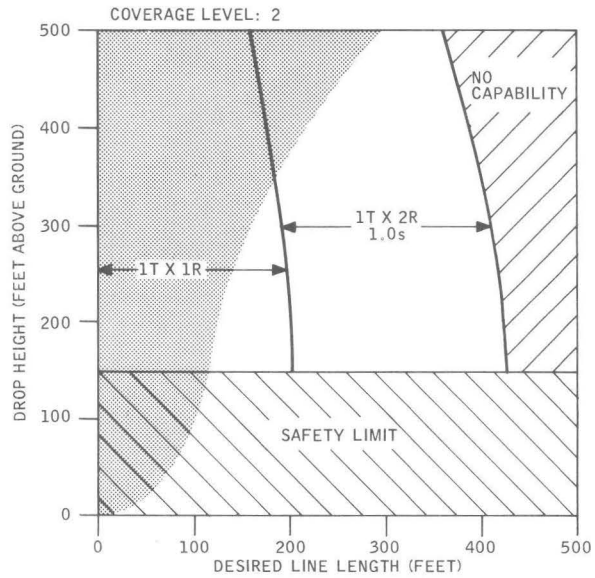
(K) If the desired drop is well within the line capability of the release strategy, consider flying higher. This will result in a wider pattern and increased safety.

Best Release Strategy - GUM-THICKENED Retardants

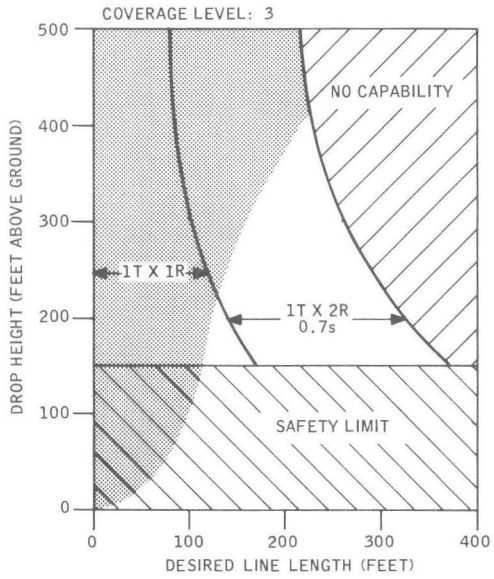
[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]



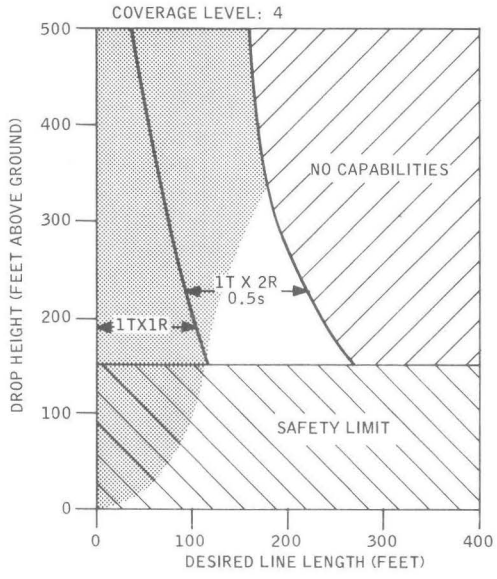
NOTE: Avoid use close to ground operations under 200-300 feet



NOTE: Avoid use close to ground operations under 200-300 feet



NOTE: Avoid use close to ground operations under 200-300 feet



NOTE: Avoid use close to ground operations under 200-300 feet

T = Tank(s) released at one time

R = Successive releases

s = seconds between successive releases

= Region of limited accuracy in direct attack

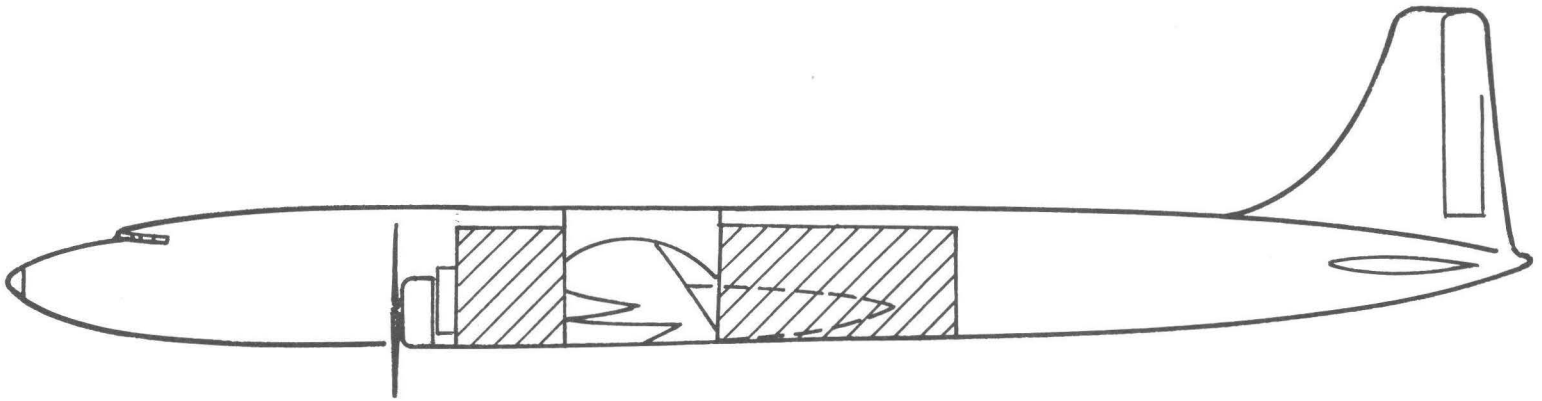
Maximum Line Lengths/Tank-Opening Delays - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

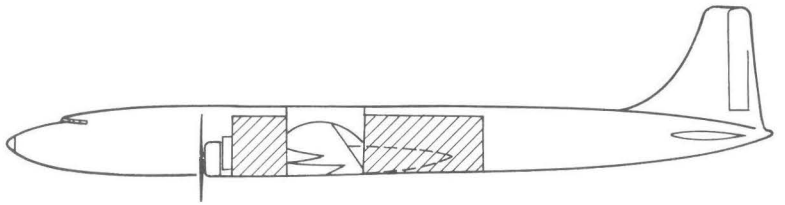
			LEVEL 1				LEVEL 2		LEVEL 3		LEVEL 4							
			COVERAGE (GALLONS/100 FT^2)															
			0.5		1.0		2.0		3.0		4.0		6.0		8.0		10.0	
NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	NO. OF PATTERNS	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)
1 TANK	150	1	340	0.0	270	0.0	205	0.0	165	0.0	115	0.0	50	0.0	20	0.0	0	0.0
		2	680	1.7	535	1.4	425	1.1	365	1.0	270	0.6	180	0.1	135	0.3	80	0.0
	300	1	310	0.0	240	0.0	190	0.0	95	0.0	70	0.0	10	0.0	0	0.0	0	0.0
		2	625	1.6	480	1.3	410	1.1	260	0.5	195	0.5	130	0.3	70	0.0	30	0.0
	500	1	295	0.0	210	0.0	150	0.0	80	0.0	30	0.0	0	0.0	0	0.0	0	0.0
		2	595	1.5	455	1.2	350	1.0	215	0.6	155	0.3	80	0.0	30	0.0	5	0.0
2 TANKS	150	1	370	0.0	315	0.0	255	0.0	215	0.0	200	0.0	160	0.0	90	0.0	60	0.0
	300	1	370	0.0	310	0.0	210	0.0	225	0.0	210	0.0	135	0.0	105	0.0	75	0.0
	500	1	325	0.0	295	0.0	235	0.0	220	0.0	175	0.0	120	0.0	75	0.0	60	0.0

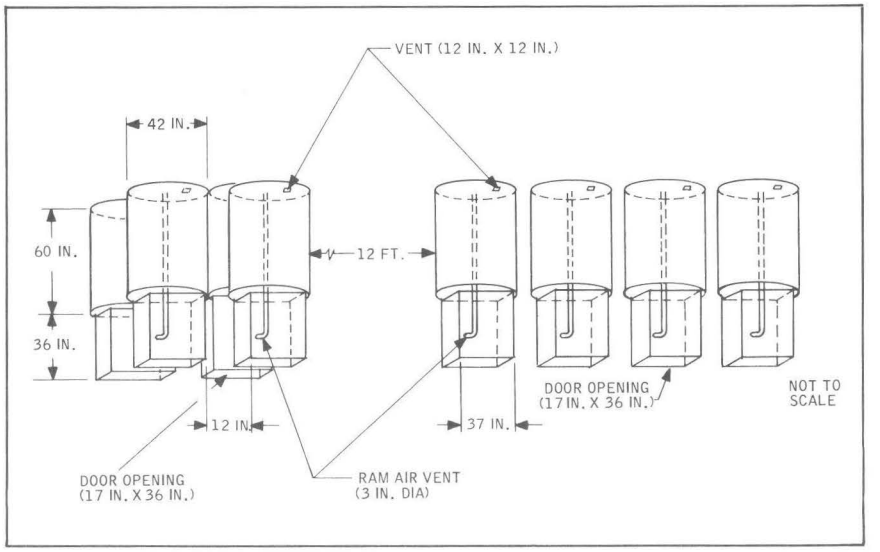
Gilbertson DC6B

RETARDANT DROP USER GUIDE
for
AERO RETARDANT INC. (GILBERTSON)
DC6B AIRCRAFT
(TANKERS 51 and 52)



Aero Retardant Inc. (Gilbertson) DC6B (Tankers 51 and 52)





The Gilbertson DC6B carries 2400 gallons of retardant in eight 350-gallon tanks. The relatively small door area and considerable separation between individual tanks contribute to early breakup of the retardant mass. When properly managed by selecting the interval between tank releases, these characteristics provide flexible, uniform coverage from low to high levels with minimal danger to ground personnel. Although the tank system offers considerable coverage at high levels, it is basically a line builder and not particularly suited to direct attack which requires high momentum to resist wind and enable the penetration of an active fire plume.

A unique characteristic of this tank system is that best usage invariably results from the proper sequencing of single-tank releases, with an interval delay ranging from about 0.5 to 1.5 seconds depending on the desired coverage level. A single 350-gallon drop does not normally produce a useful pattern (except at the lowest coverage levels). As a result, at least two tanks (700 gallons) released in a proper time sequence represents the minimum recommended drop.

The use of a small, low-flow-rate tank as a building block for a wide range of patterns, yields considerable flexibility in the tank system. It also places a premium on the aircraft intervalometer to manage the sequential addition of separate drops into continuous patterns. Although the optimum drops are based on the appropriate delay sequence, difficulties may be encountered in providing them through the current intervalometer system. In this case, two-tank and, in some cases, four-tank salvos may be useful to assure line continuity at reduced length instead of relying on the precision of a short sequence delay.

CHARACTERISTICS

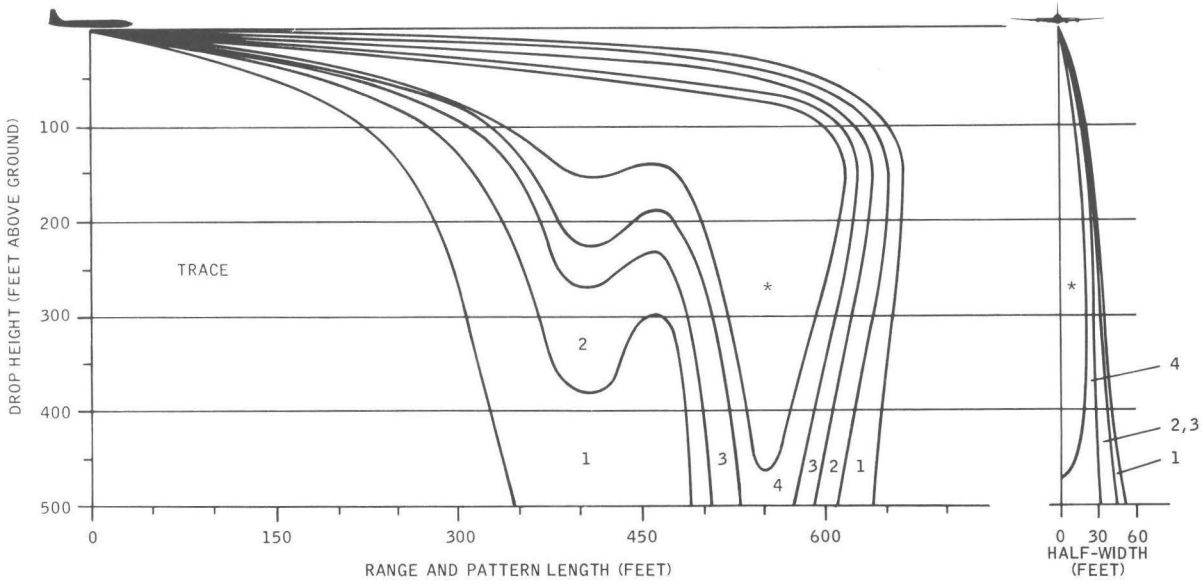
Capacity	2800 Gallons		
Increment	Eight 350-Gallon Tanks		
Tanks Released [1]	Evacuation Time (sec)	Av. Flow Rate (gallons/sec)	Peak Flow Rate (gallons/sec)
1	1.4	250	450
2	1.4	500	900
4	1.4	1000	1800
8	1.4	2000	3600

[1] Number of tanks released simultaneously

Pattern Coverage Characteristics - WATER-LIKE Retardants

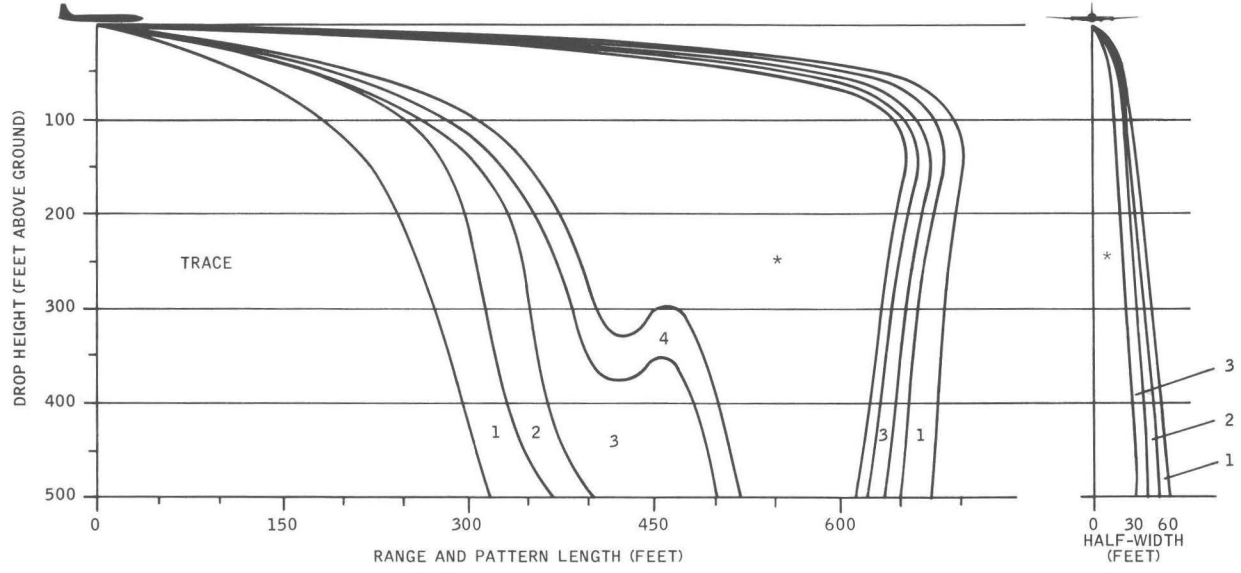
[Fire-Trol 100, Fire-Trol 931 (LC) and Water]

4-TANK, 1400-GALLON DROP



* Indicates coverage levels considerably above 5 gal/100 ft^2

8-TANK, 2800-GALLON DROP



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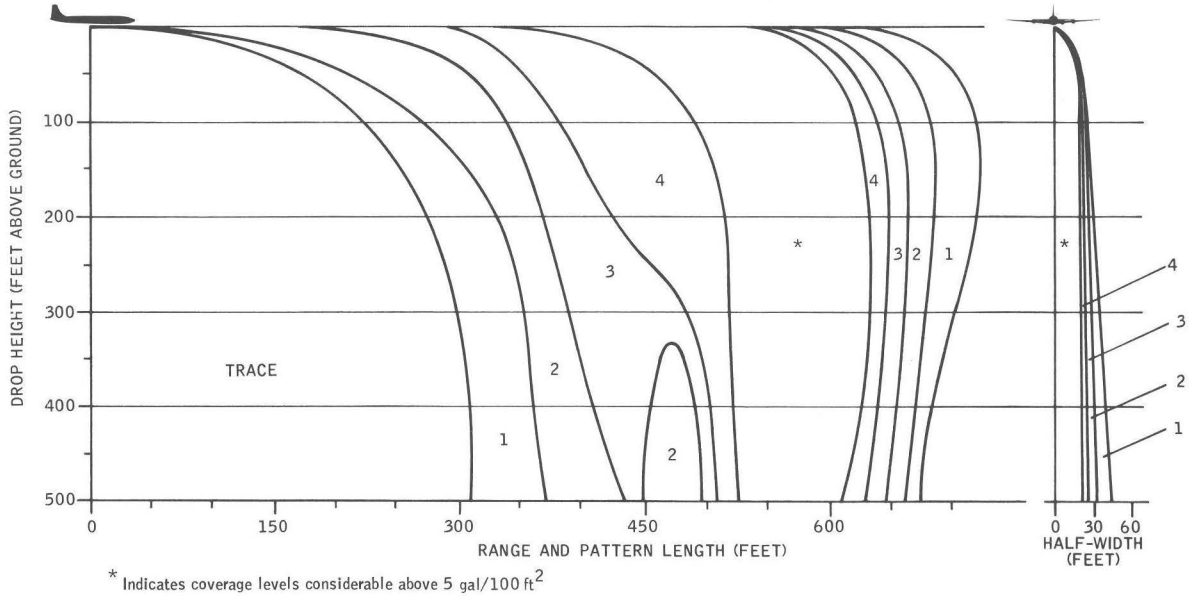
Pattern Coverage Characteristics - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

4-TANK, 1400-GALLON DROP



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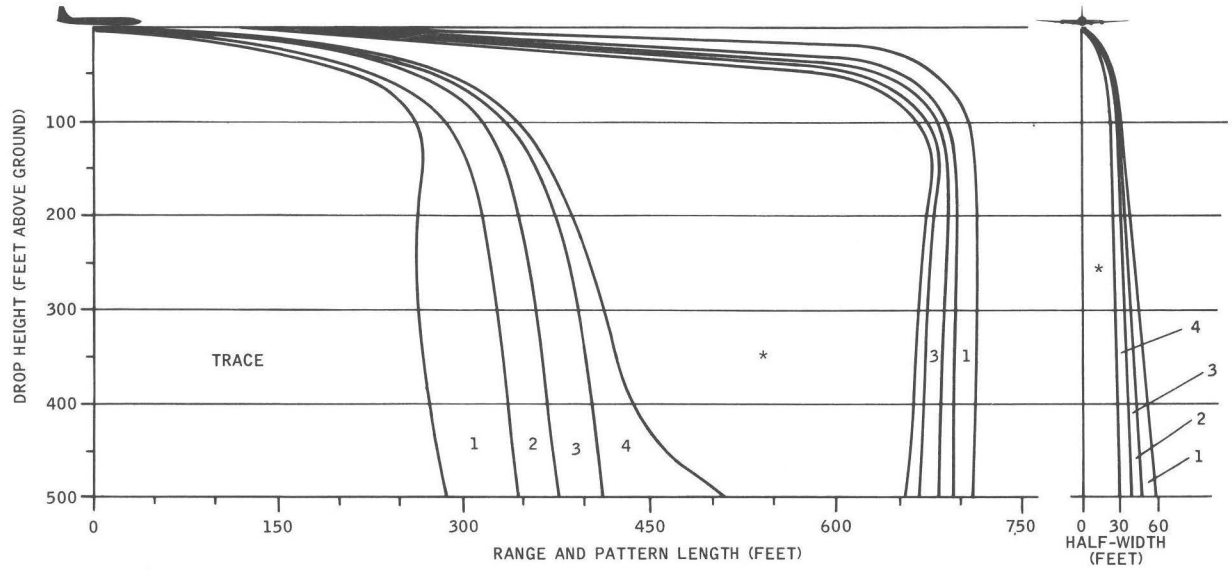
8-TANK, 2800-GALLON DROP



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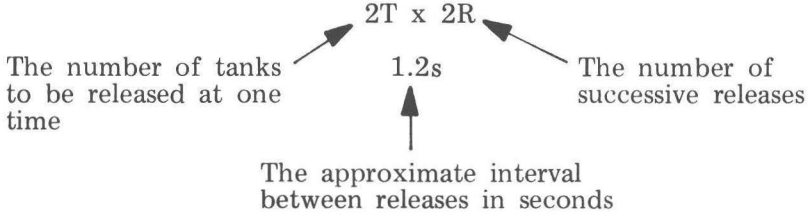
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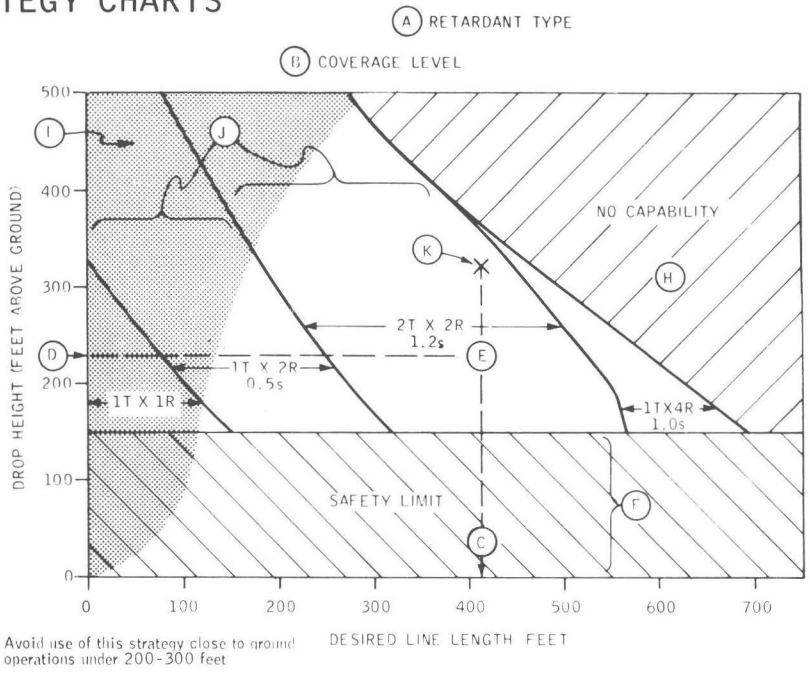

(G) NOTE: Avoid use of this strategy close to ground operations under 200-300 feet

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(G) NOTES -- Indicate recommended altitude limits for high-momentum drops potentially dangerous to ground personnel when used in close support or call out other recommendations or limitations for a particular strategy.

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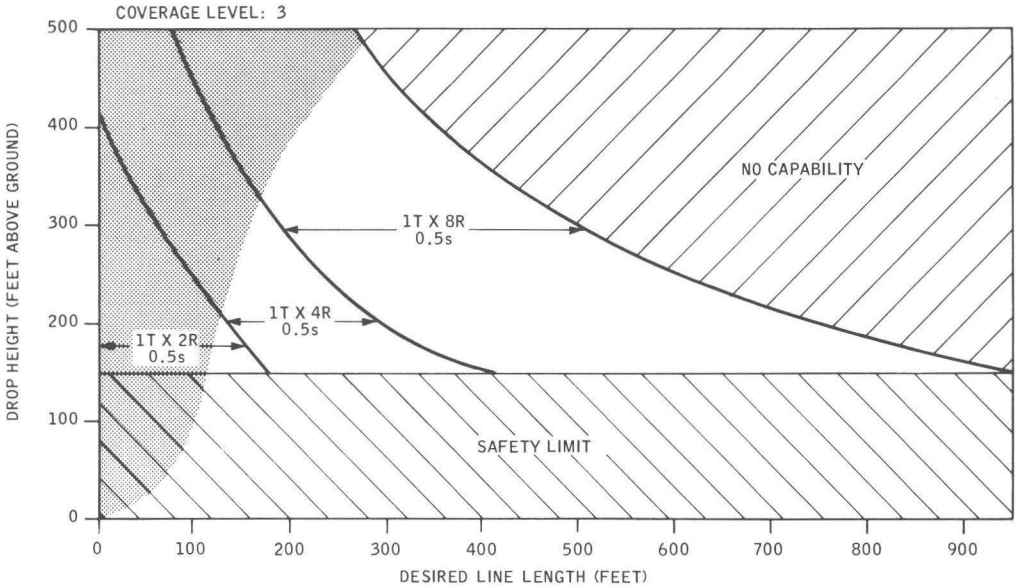
Best Release Strategy - WATER-LIKE Retardants

[Fire-Trol 100, Fire-Trol 931 (LC) and Water]

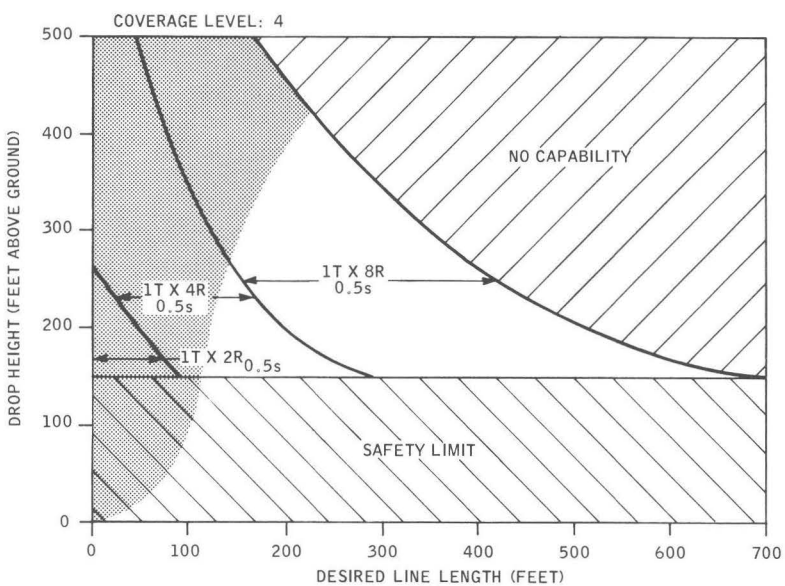


T = Tank(s) released at one time

R = Successive releases

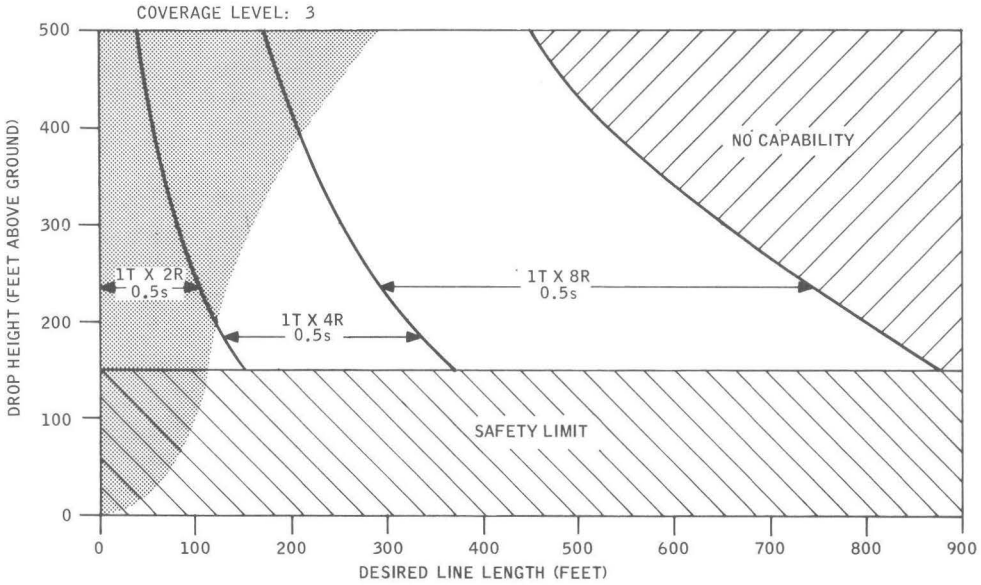
s = seconds between successive releases

= Region of limited accuracy in direct attack

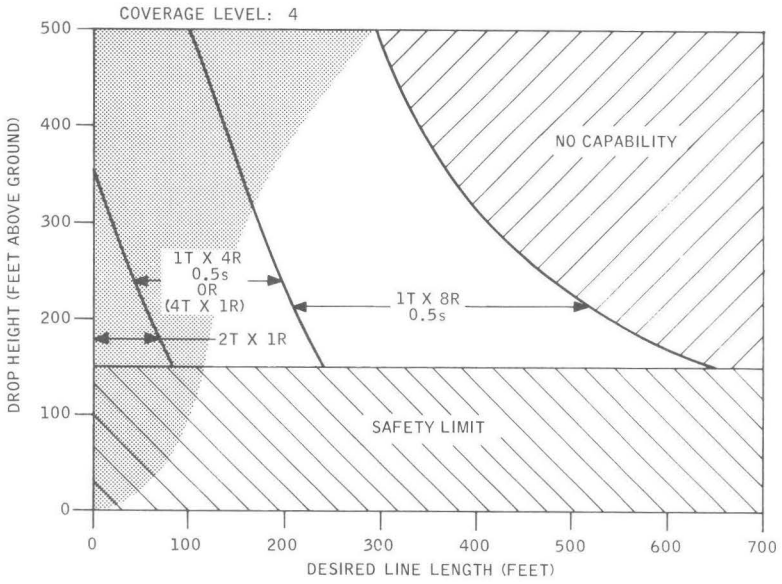


Best Release Strategy - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]



T	=	Tank(s) released at one time
R	=	Successive releases
s	=	seconds between successive releases
▒	=	Region of limited accuracy in direct attack

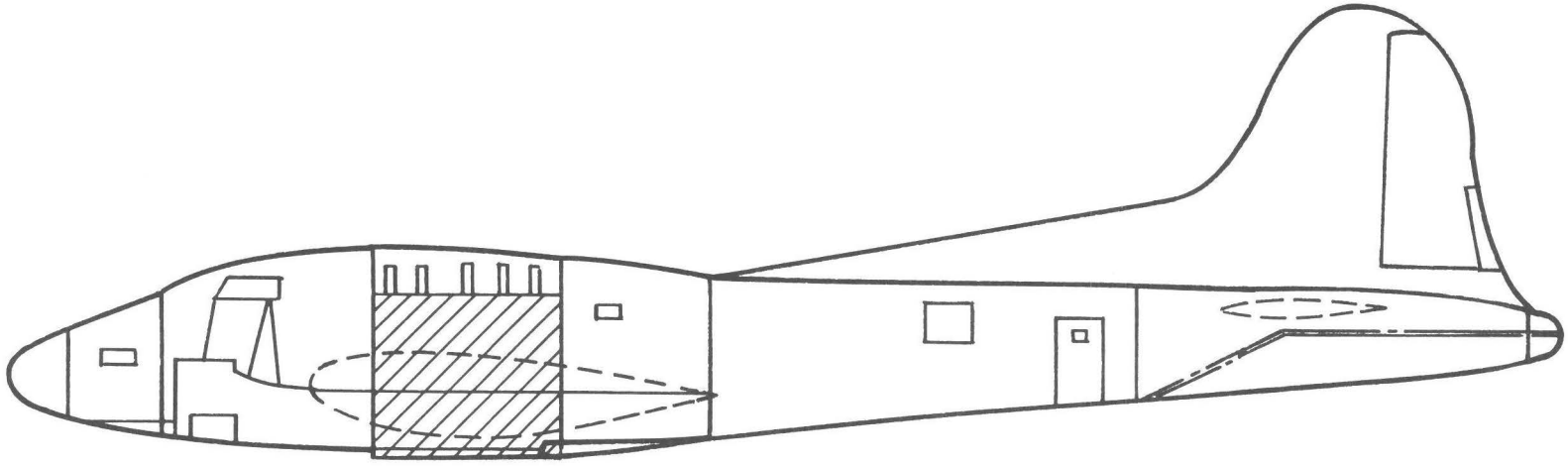


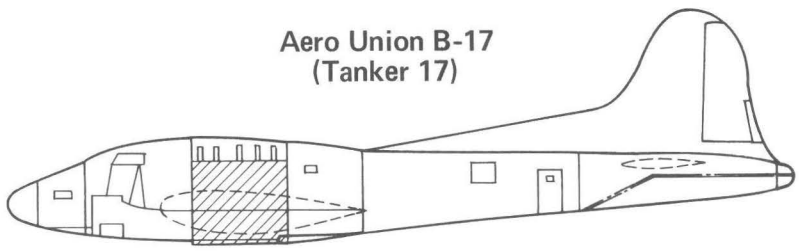
Maximum Line Lengths/Tank-Opening Delays - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

			LEVEL 1				LEVEL 2		LEVEL 3		LEVEL 4							
			COVERAGE (GALLONS/100 FT^2)															
			0.5		1.0		2.0		3.0		4.0		6.0		8.0		10.0	
NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	NO. OF PATTERNS	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)
1 TANK	150	1	335	0.0	205	0.0	80	0.0	--	--	--	--	--	--	--	--	--	--
		2	705	1.9	505	1.5	250	0.7	155	0.5	80	0.0	--	--	--	--	--	--
		4	1445	1.9	1105	1.5	545	0.8	370	0.5	255	0.4	135	0.2	80	0.0	40	0.0
		8	2925	1.9	2305	1.5	1185	0.8	885	0.7	645	0.5	350	0.2	250	0.2	175	0.1
	300	1	290	0.0	125	0.0	30	0.0	--	--	--	--	--	--	--	--	--	--
		2	615	1.7	325	0.6	185	0.6	75	0.0	30	0.0	--	--	--	--	--	--
		4	1265	1.7	680	1.0	430	0.6	240	0.4	160	0.2	75	0.0	25	0.0	--	--
		8	2565	1.7	1440	1.0	960	0.7	635	0.5	415	0.4	240	0.2	155	0.1	105	0.1
	500	1	255	0.0	100	0.0	--	--	--	--	--	--	--	--	--	--	--	--
		2	555	1.5	285	0.8	155	0.4	40	0.0	--	--	--	--	--	--	--	--
		4	1155	1.5	610	0.9	305	0.4	175	0.3	100	0.0	40	0.0	--	--	--	--
		8	2355	1.5	1330	0.9	775	0.6	440	0.4	300	0.2	165	0.1	100	0.0	70	0.0
2 TANKS	150	1	385	0.0	320	0.0	185	0.0	110	0.0	80	0.0	--	--	--	--	--	--
		2	805	2.1	680	1.8	445	1.4	290	0.8	240	0.7	150	0.5	80	0.0	45	0.0
		4	1645	2.1	1400	1.8	970	1.5	640	0.9	525	0.7	365	0.5	240	0.3	180	0.3
	300	1	375	0.0	290	0.0	120	0.0	75	0.0	25	0.0	--	--	--	--	--	--
		2	775	2.0	610	1.6	315	0.5	240	0.7	180	0.5	80	0.2	25	0.0	--	--
		4	1575	2.0	1250	1.6	675	0.9	525	0.7	430	0.6	240	0.4	165	0.3	105	0.1
	500	1	350	0.0	260	0.0	95	0.0	40	0.0	--	--	--	--	--	--	--	--
		2	730	1.9	570	1.6	270	0.8	200	0.6	105	0.3	40	0.0	--	--	--	--
		4	1490	1.9	1190	1.6	600	0.9	450	0.6	310	0.4	175	0.3	105	0.1	75	0.0
4 TANKS	150	1	490	0.0	435	0.0	370	0.0	335	0.0	240	0.0	175	0.0	145	0.0	120	0.0
		2	980	2.5	870	2.2	745	2.0	675	1.8	510	1.6	385	0.5	320	1.0	290	0.6
	300	1	455	0.0	380	0.0	290	0.0	190	0.0	120	0.0	75	0.0	25	0.0	--	--
		2	935	2.4	780	2.0	640	1.7	460	1.4	335	0.7	240	0.7	185	0.6	115	0.4
	500	1	400	0.0	355	0.0	240	0.0	130	0.0	95	0.0	40	0.0	--	--	--	--
		2	820	2.1	735	1.9	550	1.5	350	0.7	275	0.8	195	0.6	110	0.4	70	0.0
8 TANKS	150	1	565	0.0	505	0.0	430	0.0	390	0.0	350	0.0	280	0.0	185	0.0	145	0.0
	300	1	470	0.0	410	0.0	345	0.0	310	0.0	285	0.0	180	0.0	140	0.0	125	0.0
	500	1	445	0.0	375	0.0	320	0.0	275	0.0	240	0.0	115	0.0	80	0.0	65	0.0

RETARDANT DROP USER GUIDE
for
AERO UNION B-17 AIRCRAFT
(TANKER 17)



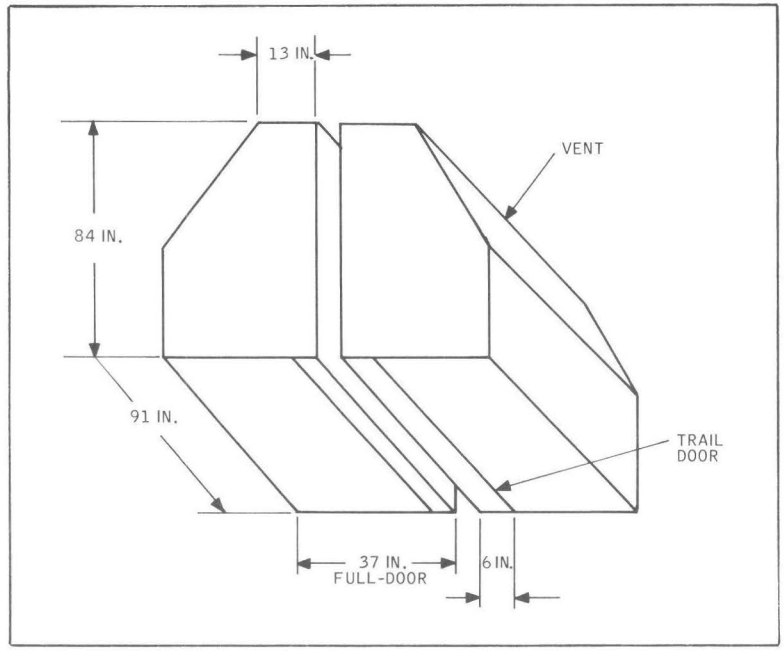


The Aero Union B-17 is equipped with two 1000-gallon tanks. Rapid door opening, large door area, and thoroughly adequate venting enable the aircraft to deliver exceptionally heavy retardant ground patterns. Trail doors allow pilot selection of a substantially lower flow-rate capable of producing considerable line at reduced coverage levels. It is thus capable of dealing with the most intense fires while preserving excellent capability for use against fires of lesser severity.

Full-door drops of 1000 or 2000 gallons produce a retardant mass with considerable momentum. It is wind resistant, accurate, and should penetrate intense fire plumes in quantities adequate for direct suppression. It has the capability to physically break vertical fuel structures (top or uproot trees, etc.) and represents a classic example of a tank system specifically designed for the direct suppression of intense spot fires by aircraft operations alone. Because of this capability, the full-door modes should be used with extreme care in any drops close to ground operations. The full-door two-tank drop should not be used and the full-door single-tank drop should be avoided at drop heights of less than about 300 feet.

Except for very high coverage levels (4 or better), best usage will normally be achieved by sequencing two single-tank drops or by employing the trail doors. The intervalometer on the aircraft is not readily accessible to the pilot, but the appropriate delay of 1 to 1½ seconds can be reasonably estimated by the pilot, and tank performance is not particularly sensitive to estimate errors in this range.

For line building at lower coverage levels (1 or 2), the trail doors should be employed, with a delay between tanks of 1 to 4 seconds. The 4-second delay should provide the most line at a coverage level of 1. Estimation errors on the short side reduce line length with a slight increase in coverage level. Errors above 4 seconds can produce discontinuities in the line.



CHARACTERISTICS

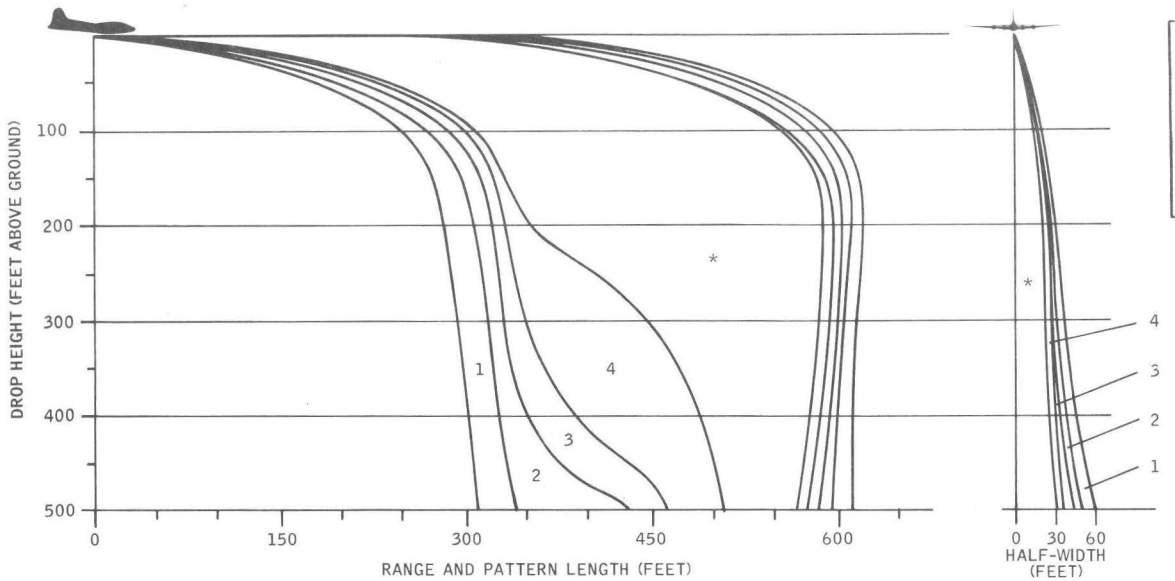
Capacity	2000 Gallons		
Increment	Two 1000-Gallon Tanks Salvo or Trail		
Tanks Released [1]	Evacuation Time (sec)	Av. Flow Rate (gallons/sec)	Peak Flow Rate (gallons/sec)
Full Door			
1	0.68	1470	2700
2	0.68	2940	5400
Trail Door			
1	4.26	235	315
2	4.26	470	630

[1] Number of tanks released simultaneously

Pattern Coverage Characteristics - WATER-LIKE Retardants

[Fire-Trol 100, Fire-Trol 931 (LC) and Water]

2-TANK, 2000-GALLON DROP



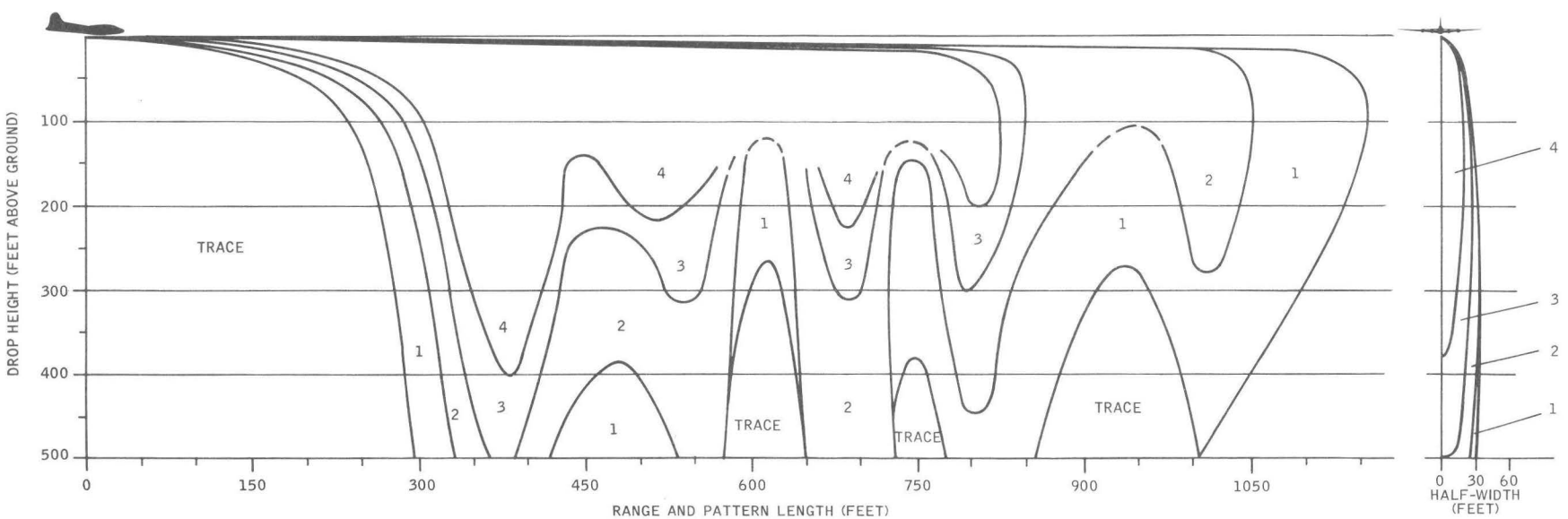
* Indicates coverage levels considerably above 5 gal/100 ft^2

USE OF PATTERN FOOTPRINTS

Pattern footprints provide information on aircraft capability at various coverage levels. The presentation allows estimation of ground range from point of release to the center (deepest penetration) of the pattern. It shows where pattern coverage is relatively constant with increasing altitude, useful to develop width and increase operating safety, and where small increases in altitude cause rapid decreases in some coverage levels. The footprints also indicate, by comparison, the differences in operations related to retardant type.

- Drop Speed: 120 knots
- Coverage levels in gallons per 100 square feet

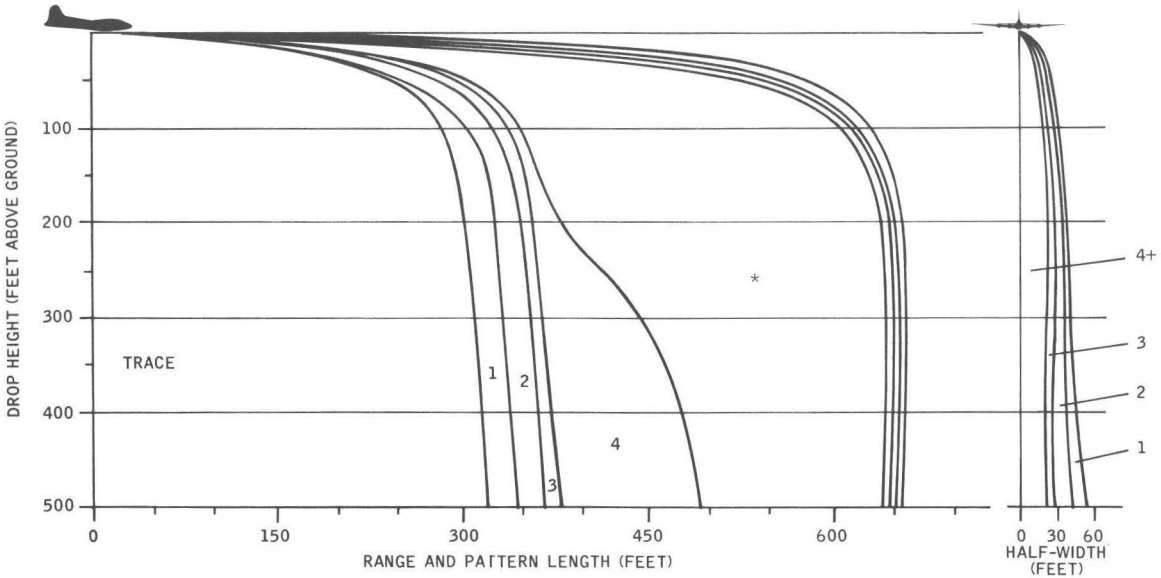
2-TANK, TRAIL-DOOR DROP



Pattern Coverage Characteristics - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

2-TANKS, 2000-GALLON DROP



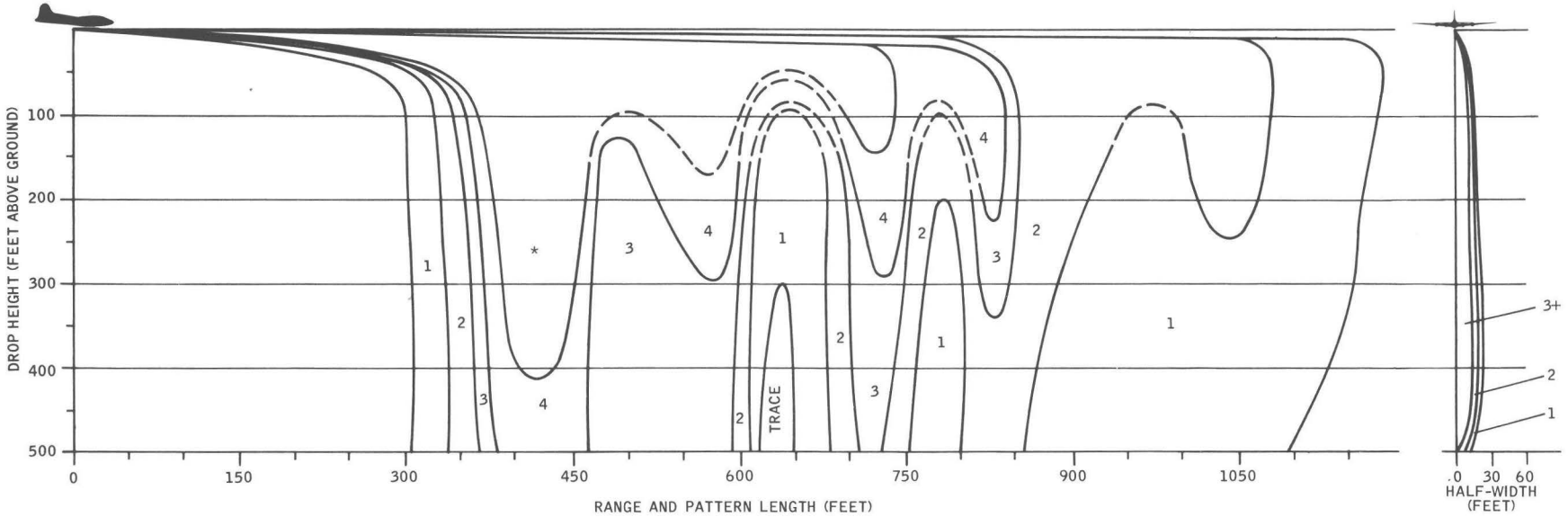
*Indicates coverage levels considerably above 5 gal/100 ft^2

USE OF PATTERN FOOTPRINTS

Pattern footprints provide information on aircraft capability at various coverage levels. The presentation allows estimation of ground range from point of release to the center (deepest penetration) of the pattern. It shows where pattern coverage is relatively constant with increasing altitude, useful to develop width and increase operating safety, and where small increases in altitude cause rapid decreases in some coverage levels. The footprints also indicate, by comparison, the differences in operations related to retardant type.

- Drop Speed: 120 knots
- Coverage levels in gallons per 100 square feet

2-TANK, TRAIL-DOOR DROP



* Indicates coverage levels considerably above 5 gal/100 ft^2

USE OF THE BEST-STRATEGY CHARTS

(A) Select the charts for the retardant type to be employed in the operations. This will be GUM-THICKENED (such as Phos-Chek) or WATER-LIKE (such as Fire-Trol 100).

(B) Select the chart for the appropriate coverage level for fuel and fire situations in the area of operations.

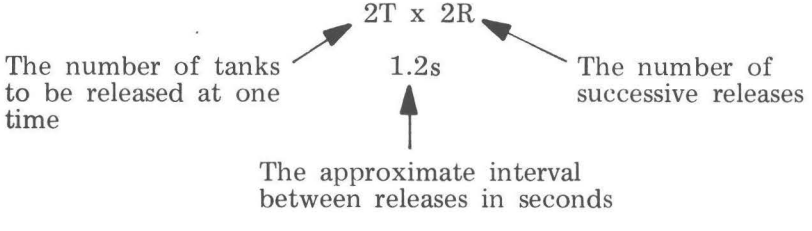
Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

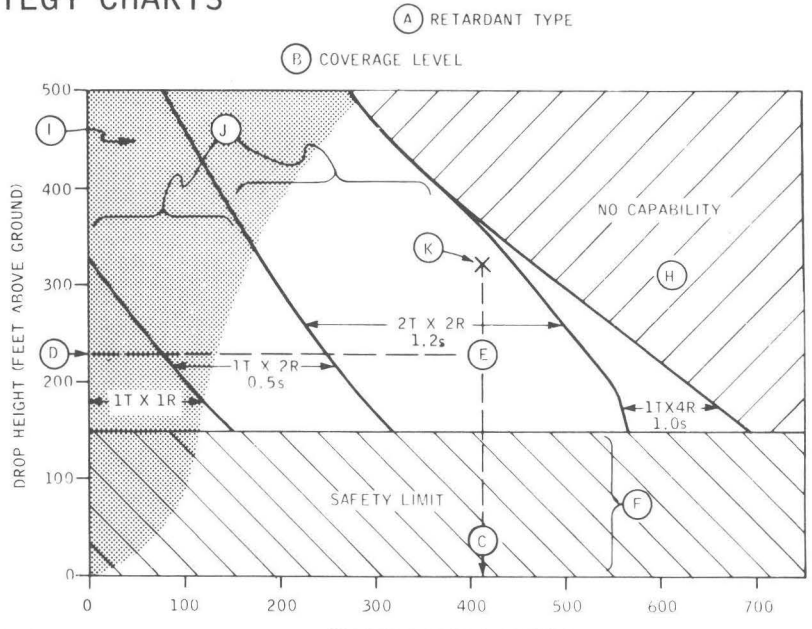
For creeping or smouldering fires reduction of one coverage level may be considered.

(C) Estimate the length of line required for a particular drop at the selected coverage level.

(D) Determine drop-height limits: (1) to assure aircraft safety in clearance of terrain features both before and after the planned release and (2) to protect ground personnel in close-support operations.

(E) Identify the region on the chart defined by the line-length, drop-height condition. This will identify the best release strategy to achieve the required coverage:


2T x 2R
1.2s
The number of tanks to be released at one time
The number of successive releases
The approximate interval between releases in seconds



(F) SAFETY LIMIT -- Usually expressed as a fuel clearance distance; will normally be at 150 feet above ground or greater depending on terrain or fuel features

(G) NOTES -- Indicate recommended altitude limits for high-momentum drops potentially dangerous to ground personnel when used in close support or call out other recommendations or limitations for a particular strategy.

(H) LIMITS OF CAPABILITY -- The aircraft cannot produce, in a single pass, line-length greater than that defined by the limit curve.

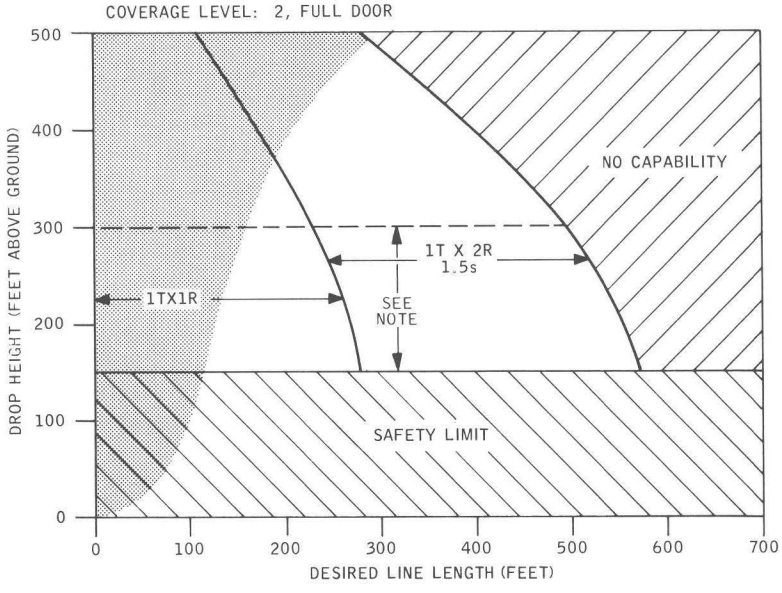
(I) REGION OF LIMITED ACCURACY -- The ability to place a pattern of the specified coverage level on a spot fire is doubtful if operations must be conducted in this region.

(J) OPERATING REGIONS -- Most efficient use of the available retardant and pattern controls will occur for the strategy listed. For more precise intervalometer settings see the detailed tables.

(K) If the desired drop is well within the line capability of the release strategy, consider flying higher. This will result in a wider pattern and increased safety.

Best Release Strategy - WATER-LIKE Retardants

[Fire-Trol 100, Fire-Trol 931 (LC) and Water]



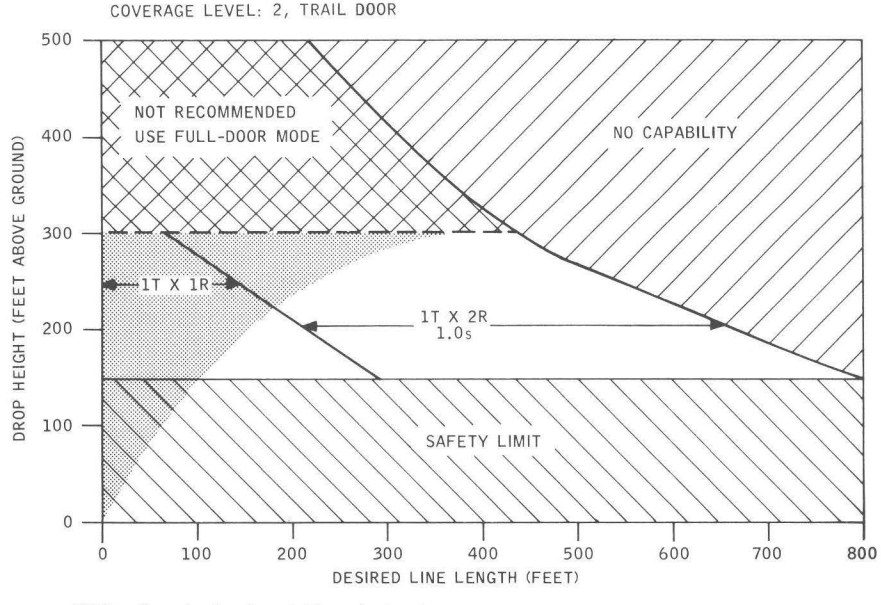
NOTE: Use trail-door mode for drops close to ground operations

T = Tank(s) released at one time

R = Successive releases

s = seconds between successive releases

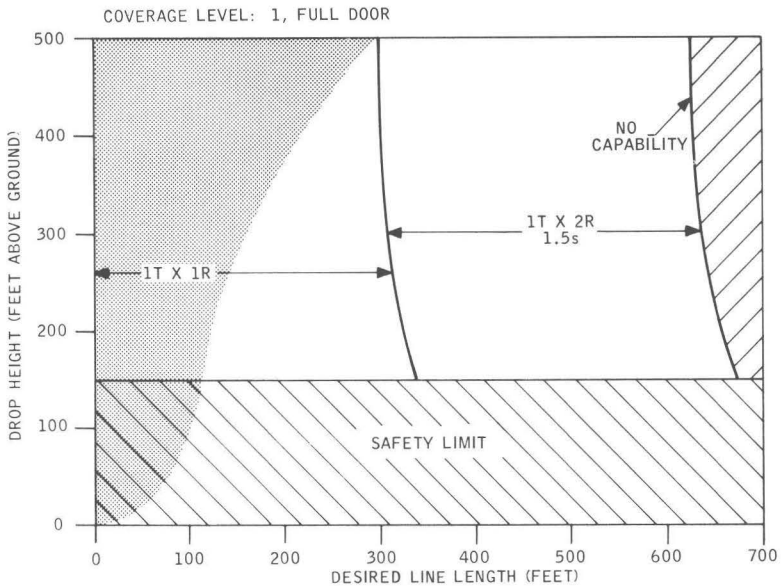
= Region of limited accuracy in direct attack



NOTE: Use only when drop must be made close to ground operations

Best Release Strategy - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]



T = Tank(s) released at one time

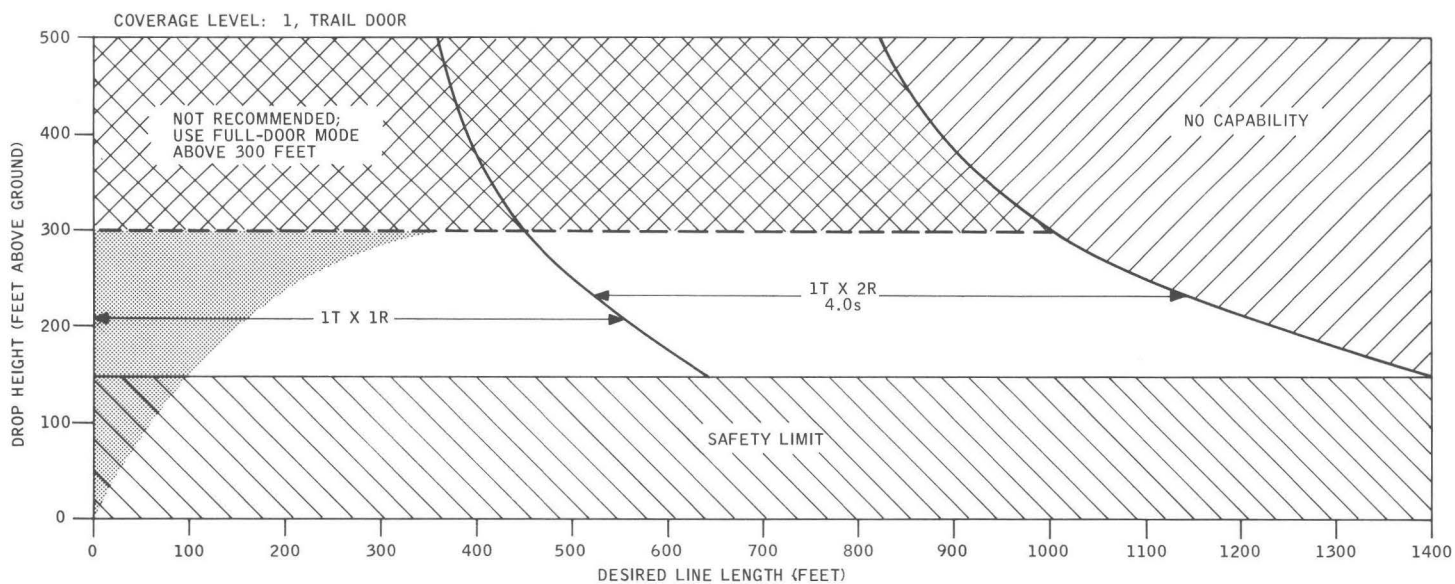
R = Successive releases

s = seconds between successive releases

= Region of limited accuracy in direct attack

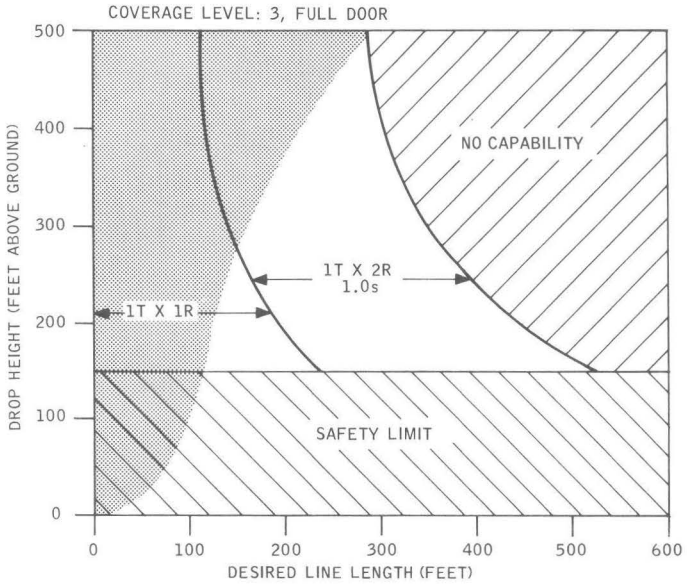
NOTES: Use for direct attack only; otherwise use trail-door mode

Use trail-door mode in operations close to ground personnel



Best Release Strategy - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]



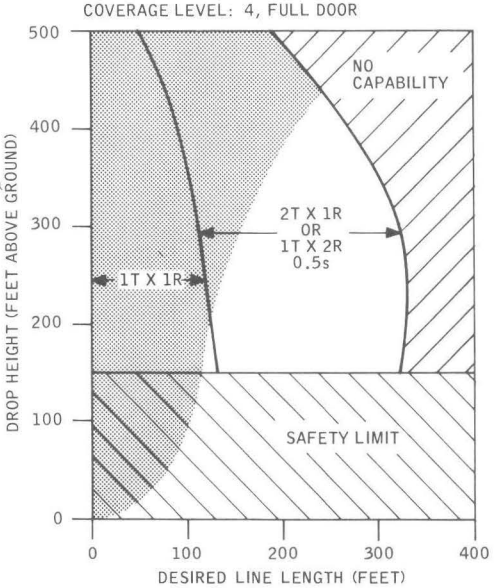
NOTE: Avoid use close to ground operations under 200-300 feet

T = Tank(s) released at one time

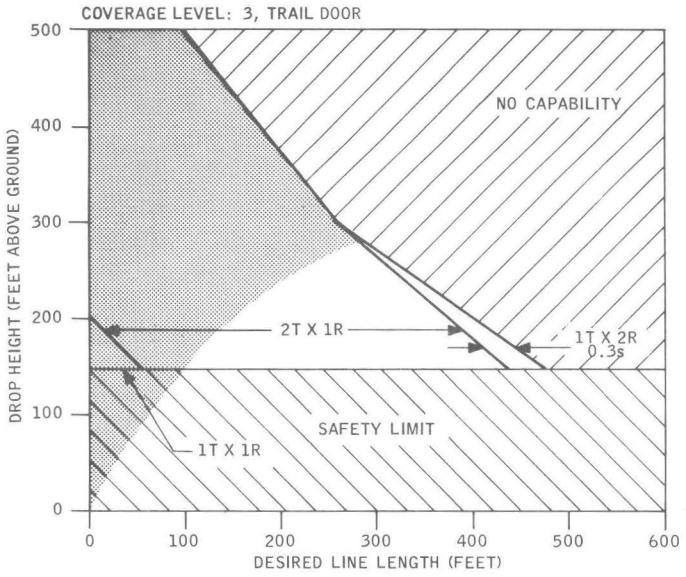
R = Successive releases

s = seconds between successive releases

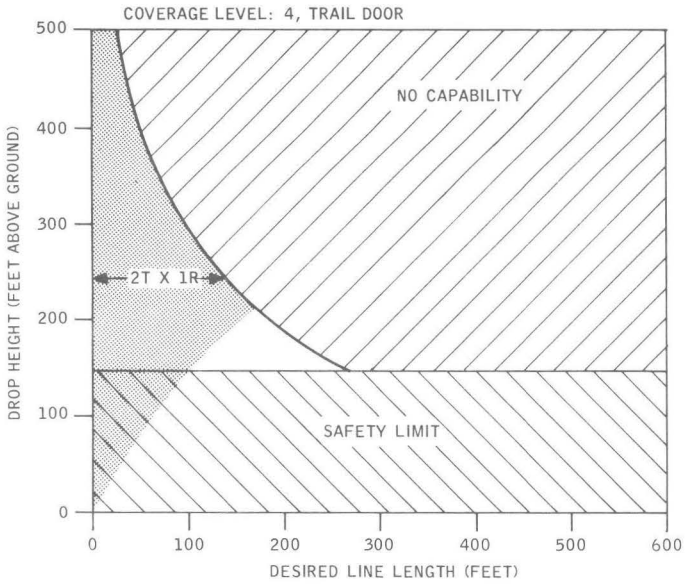
= Region of limited accuracy in direct attack



NOTE: Avoid use close to ground operations under 200-300 feet



NOTE: Use only when drops are close to ground operations



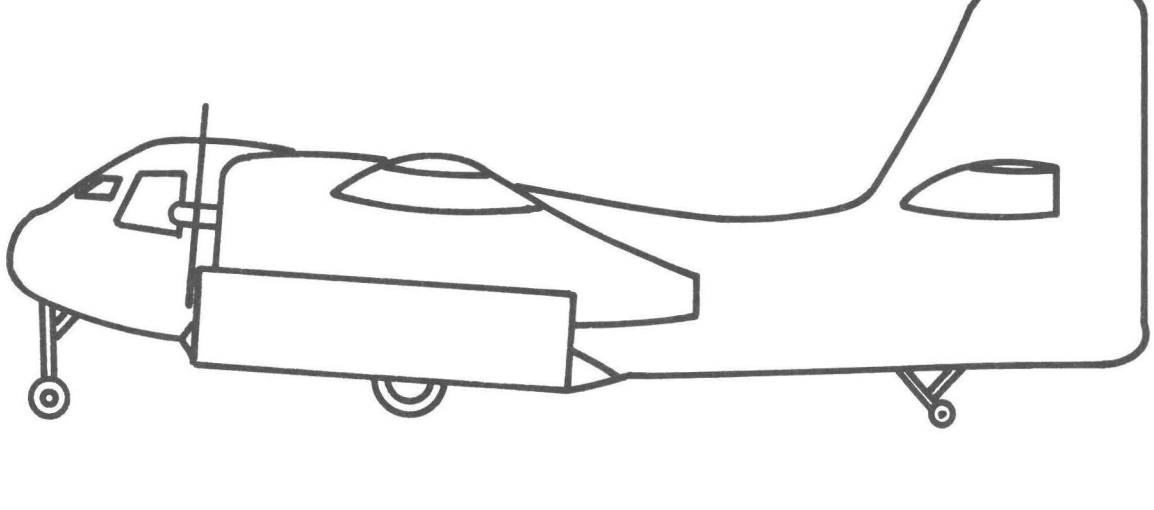
NOTE: Use only when drops are close to ground operations

Maximum Line Lengths/Tank-Opening Delays - GUM-THICKENED Retardants

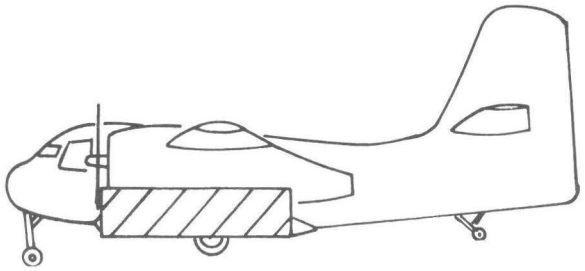
[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

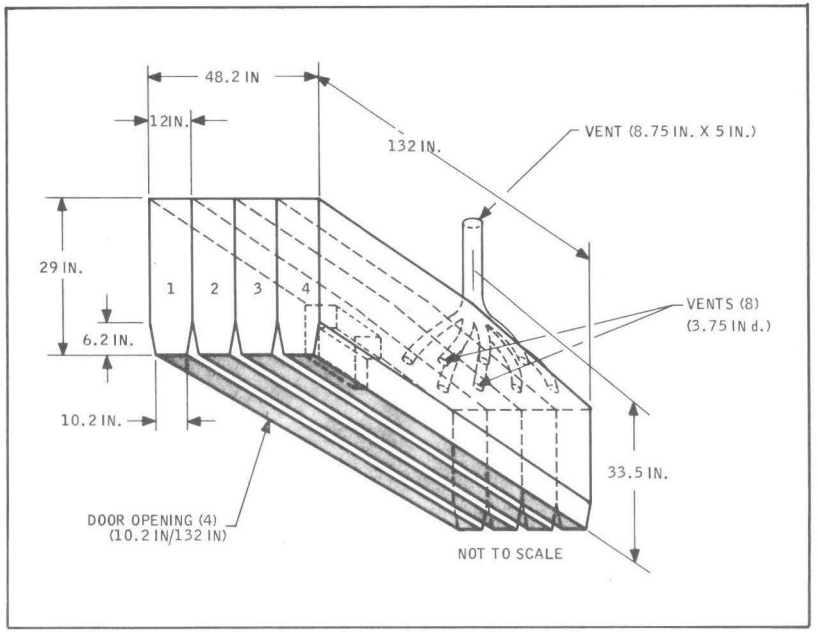
NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	NO. OF PATTERNS	LEVEL 1				LEVEL 2		LEVEL 3		LEVEL 4							
			COVERAGE (GALLONS/100 FT^2)															
			0.5		1.0		2.0		3.0		4.0		6.0		8.0		10.0	
			MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)
FULL DOOR																		
1 TANK	150	1	360	0.0	335	0.0	290	0.0	240	0.0	135	0.0	85	0.0	10	0.0	--	--
		2	725	1.4	675	1.7	600	1.6	520	1.4	340	0.9	260	0.1	160	0.3	115	0.0
	300	1	350	0.0	310	0.0	270	0.0	135	0.0	105	0.0	10	0.0	--	--	--	--
		2	705	1.8	630	1.6	570	1.5	335	0.9	270	0.0	155	0.2	105	0.0	55	0.0
	500	1	340	0.0	300	0.0	200	0.0	115	0.0	50	0.0	--	--	--	--	--	--
		2	690	1.8	620	1.6	445	1.4	280	0.6	230	0.4	115	0.0	55	0.2	--	--
2 TANKS	150	1	410	0.0	380	0.0	355	0.0	335	0.0	325	0.0	295	0.0	180	0.0	155	0.0
	300	1	395	0.0	375	0.0	350	0.0	330	0.0	315	0.0	200	0.0	170	0.0	120	0.0
	500	1	355	0.0	335	0.0	300	0.0	275	0.0	190	0.0	115	0.0	60	0.0	--	--
TRAIL DOOR																		
1 TANK	150	1	890	0.0	645	0.0	245	0.0	60	0.0	--	--	--	--	--	--	--	--
		2	1810	4.6	1395	4.4	775	1.1	465	0.3	245	0.0	60	0.0	--	--	--	--
	300	1	665	0.0	440	0.0	85	0.0	--	--	--	--	--	--	--	--	--	--
		2	1765	4.5	995	3.2	575	0.9	255	0.0	85	0.0	--	--	--	--	--	--
	500	1	735	0.0	360	0.0	40	0.0	--	--	--	--	--	--	--	--	--	--
		2	1540	4.4	825	1.9	360	0.0	105	0.4	40	0.0	--	--	--	--	--	--
2 TANKS	150	1	920	0.0	880	0.0	620	0.0	420	0.0	260	0.0	70	0.0	--	--	--	--
	300	1	910	0.0	835	0.0	450	0.0	255	0.0	85	0.0	--	--	--	--	--	--
	500	1	890	0.0	690	0.0	375	0.0	100	0.0	40	0.0	--	--	--	--	--	--

RETARDANT DROP USER GUIDE
for
HEMET VALLEY-S2F AIRCRAFT
(CDF TANKERS-70 and 71)



Hemet Valley - S2F
(CDF Tankers - 70 and 71)





The Hemet Valley S2F carries 800 gallons of retardant in four 200-gallon tanks. The tank venting system restricts air entry during retardant release and prevents the build-up of high flow rates. This feature with the ability to sequence the four tanks, produces a highly efficient line-building capability at low coverage levels (1 or 2). It generates a low-momentum retardant cloud that is relatively safe for use near ground personnel even in the full 800-gallon salvo mode. There is some evidence, however, that control of flow rate by means of restrictive venting can cause considerable variation from drop to drop. As a consequence, sequenced delivery should be considered as an alternative to the 800-gallon salvo in developing patterns of high coverage levels (3 or 4) close to ground operations.

The tank's capability to produce high-coverage-level patterns is relatively limited. Since it also produces a relatively low-momentum drop, direct attack on intense fires in heavy fuels should only be conducted from low altitude under favorable wind conditions.

The aircraft is equipped with an intervalometer for setting an automatic delay for tank sequencing of up to 30 seconds. The appropriate delays, on the order of 0.5 to 1.2 seconds, are difficult to select using the automatic mode. In practice, pilot-estimated delays should be employed ranging from (1) quick sequential pickling (about as fast as the button can be triggered), (2) a one-second delay, or (3) reverting to the appropriate salvo mode.

CHARACTERISTICS

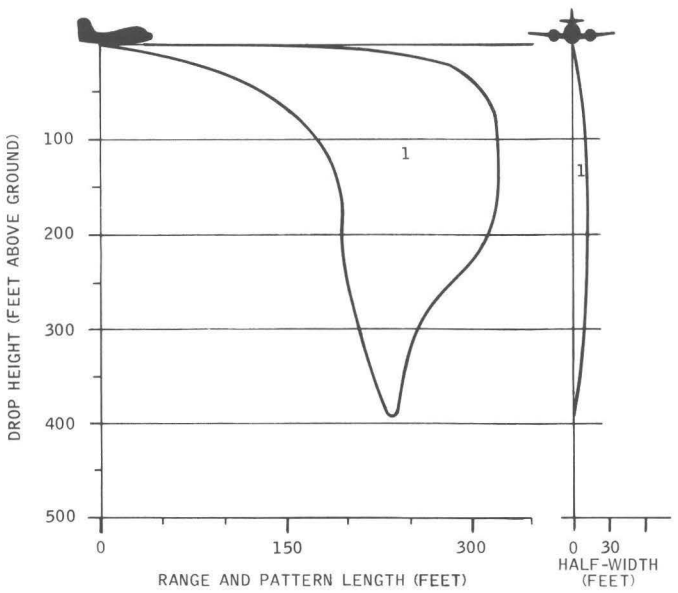
Capacity	800 Gallons		
Increment	Four 200-Gallon Tanks		
Tanks Released [1]	Evacuation Time (sec)	Av Flow Rate (gallons/sec)	Peak Flow Rate (gallons/sec)
1	1.0	200	350
2	1.1	360	670
4	1.2	670	1000

[1] Number of tanks released simultaneously

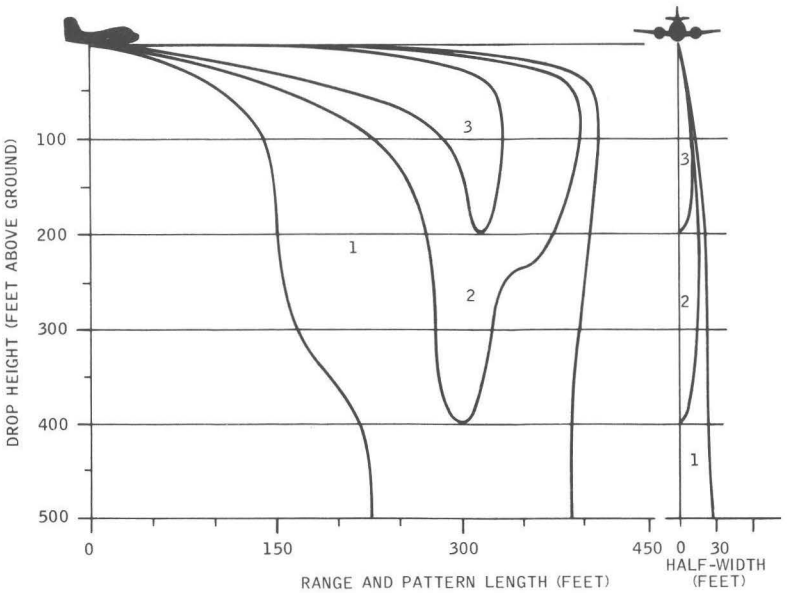
Pattern Coverage Characteristics - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

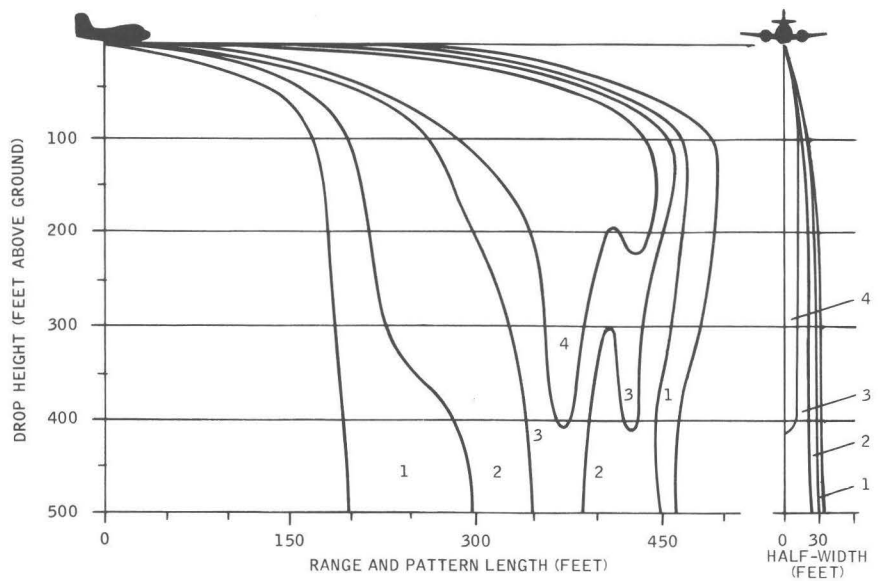
1-TANK, 200-GALLON DROP



2-TANK, 400-GALLON DROP



4-TANK, 800-GALLON DROP



Coverage Level	Recommended For:	
	Fuel Model	Description
1	A	Grasses; tundra, and open desert shrub lands
2	C	Conifer timber with grass understory
	F	Brushfields with much green material
3	D	Shrublands under 6 feet in height (such as sagebrush)
	E	Hardwood litter after leaf drop
	H	Closed conifer timber with litter only
4	B	Hard chaparral and other high (6-foot) flammable shrubs
	G	Closed, old conifer timber with litter and dead, down limb wood.
	I	Conifer slash

For creeping or smouldering fires reduction of one coverage level may be considered.

USE OF THE BEST-STRATEGY CHARTS

(A) Select the charts for the retardant type to be employed in the operations. This will be GUM-THICKENED (such as Phos-Chek) or WATER-LIKE (such as Fire-Trol 100).

(B) Select the chart for the appropriate coverage level for fuel and fire situations in the area of operations.

Coverage Level	Recommended For:	
	Fuel Model	Description
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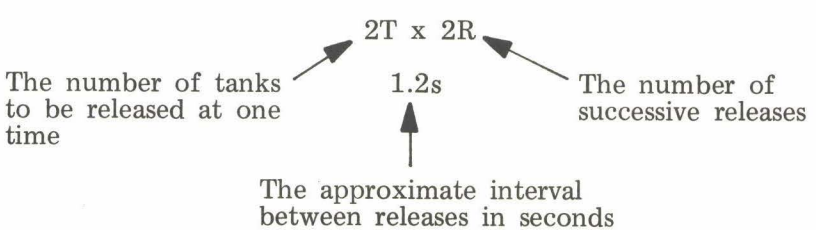
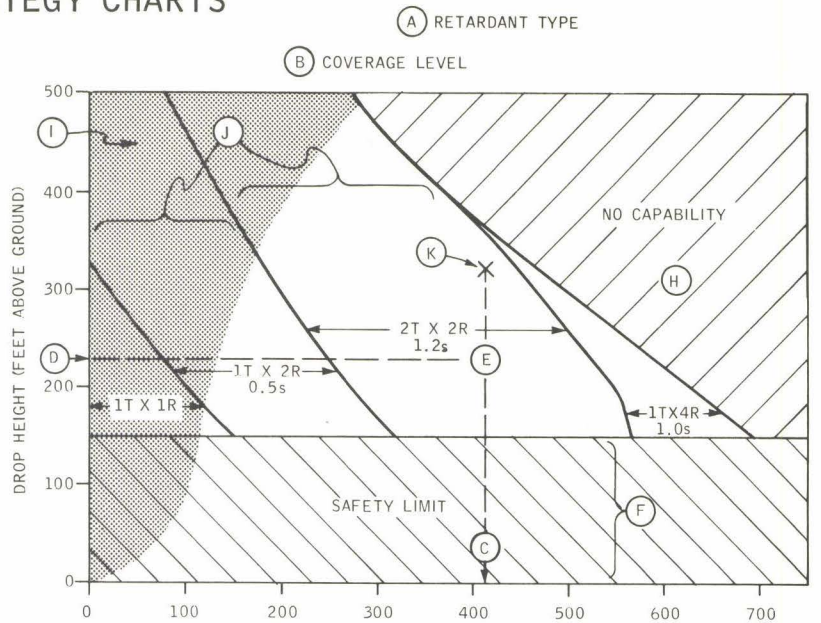
For creeping or smouldering fires reduction of one coverage level may be considered.

(C) Estimate the length of line required for a particular drop at the selected coverage level.

(D) Determine drop-height limits: (1) to assure aircraft safety in clearance of terrain features both before and after the planned release and (2) to protect ground personnel in close-support operations.

(E) Identify the region on the chart defined by the line-length, drop-height condition. This will identify the best release strategy to achieve the required coverage:


2T x 2R
1.2s
The number of tanks to be released at one time
The number of successive releases
The approximate interval between releases in seconds



(G) NOTE: Avoid use of this strategy close to ground operations under 200-300 feet

(F) SAFETY LIMIT -- Usually expressed as a fuel clearance distance; will normally be at 150 feet above ground or greater depending on terrain or fuel features

(G) NOTES -- Indicate recommended altitude limits for high-momentum drops potentially dangerous to ground personnel when used in close support or call out other recommendations or limitations for a particular strategy.

(H) LIMITS OF CAPABILITY -- The aircraft cannot produce, in a single pass, line-length greater than that defined by the limit curve.

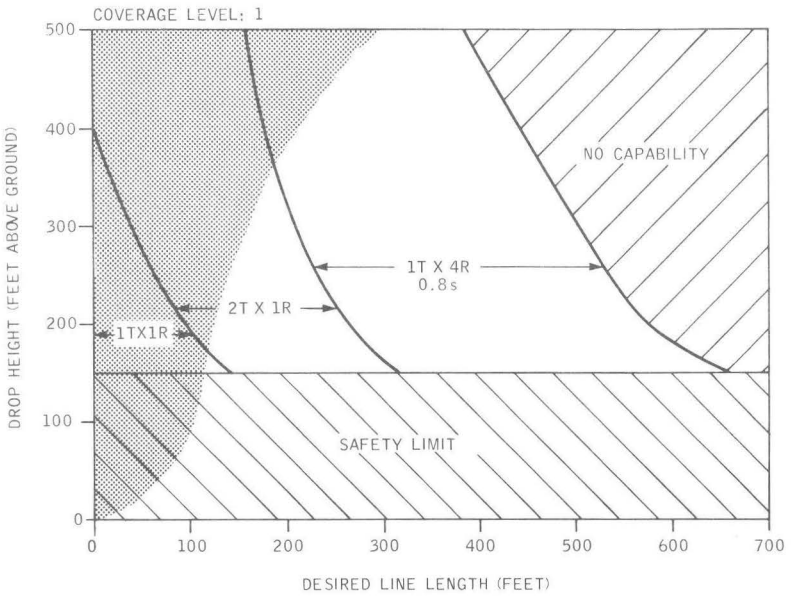
(I) REGION OF LIMITED ACCURACY -- The ability to place a pattern of the specified coverage level on a spot fire is doubtful if operations must be conducted in this region.

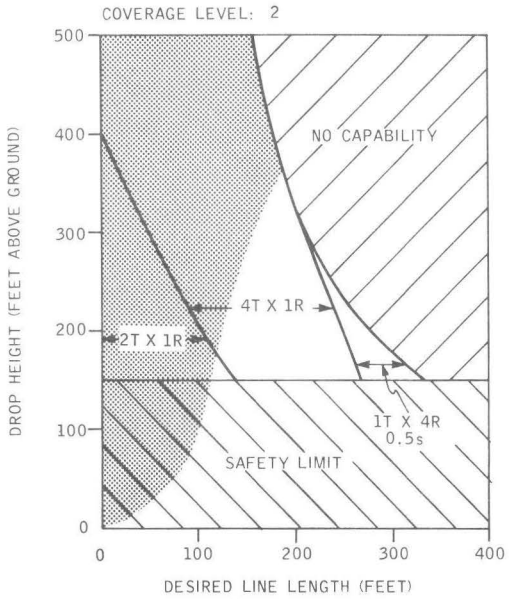
(J) OPERATING REGIONS -- Most efficient use of the available retardant and pattern controls will occur for the strategy listed. For more precise intervalometer settings see the detailed tables.

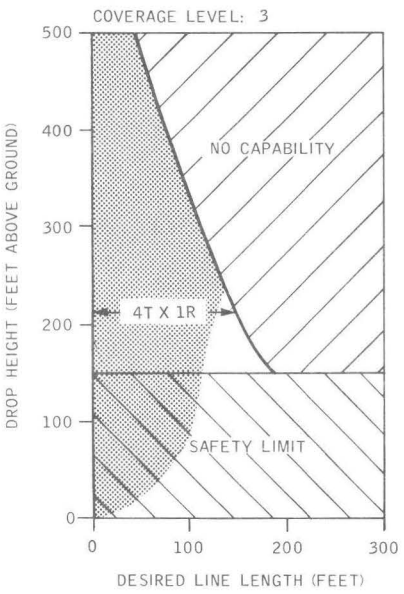
(K) If the desired drop is well within the line capability of the release strategy, consider flying higher. This will result in a wider pattern and increased safety.

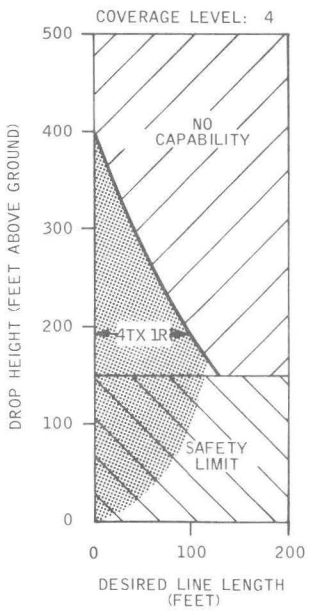
Best Release Strategy - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]









T = Tank(s) released at one time

R = Successive releases

s = seconds between successive releases

= Region of limited accuracy in direct attack

Maximum Line Lengths/Tank-Opening Delays - GUM-THICKENED Retardants

[Phos-Chek XA, Gelgard and Gum-Thickened Fire-Trol 931 (LC)]

			LEVEL 1				LEVEL 2		LEVEL 3		LEVEL 4			
			COVERAGE (GALLONS/100 FT^2)											
			0.5		1.0		2.0		3.0		4.0		6.0	
NO. OF TANKS RELEASED AT A TIME	DROP HEIGHT (FT)	NO. OF PATTERNS	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)	MAX LENGTH (FT)	DELAY (SEC)
1 TANK	150	1	260	0.0	135	0.0	--	--	--	--	--	--	--	--
		2	545	1.5	315	0.9	135	0.0	5	0.0	--	--	--	--
		4	1115	1.5	675	0.9	340	0.6	200	0.0	130	0.0	5	0.0
	200	1	255	0.0	90	0.0	--	--	--	--	--	--	--	--
		2	535	1.4	265	0.8	100	0.2	--	--	--	--	--	--
		4	1095	1.4	585	0.8	275	0.4	160	0.2	95	0.1	--	--
	300	1	245	0.0	50	0.0	--	--	--	--	--	--	--	--
		2	525	1.4	245	0.0	50	0.0	--	--	--	--	--	--
		4	1085	1.4	520	0.8	245	0.0	130	0.0	50	0.0	--	--
	400	1	160	0.0	--	--	--	--	--	--	--	--	--	--
		2	365	1.3	180	0.5	--	--	--	--	--	--	--	--
		4	775	1.3	455	0.7	180	0.2	90	0.1	--	--	--	--
	500	1	160	0.0	--	--	--	--	--	--	--	--	--	--
		2	365	1.3	175	0.3	--	--	--	--	--	--	--	--
		4	775	1.3	400	0.7	160	0.0	50	0.0	--	--	--	--
2 TANKS	150	1	315	0.0	265	0.0	125	0.0	10	0.0	--	--	--	--
		2	640	1.7	555	1.5	315	0.9	185	0.2	125	0.0	10	0.0
	200	1	305	0.0	260	0.0	95	0.0	--	--	--	--	--	--
		2	625	1.6	545	1.5	275	0.8	165	0.4	95	0.0	--	--
	300	1	295	0.0	230	0.0	35	0.0	--	--	--	--	--	--
		2	605	1.6	490	1.3	230	0.0	125	0.0	35	0.0	--	--
	400	1	290	0.0	185	0.0	5	0.0	--	--	--	--	--	--
		2	595	1.6	410	1.2	185	0.0	90	0.2	5	0.0	--	--
	500	1	280	0.0	160	0.0	--	--	--	--	--	--	--	--
		2	580	1.5	365	1.0	165	0.5	45	0.0	--	--	--	--
4 TANKS	150	1	345	0.0	315	0.0	270	0.0	190	0.0	125	0.0	15	0.0
	200	1	345	0.0	310	0.0	260	0.0	165	0.0	75	0.0	--	--
	300	1	320	0.0	295	0.0	210	0.0	125	0.0	35	0.0	--	--
	400	1	320	0.0	290	0.0	185	0.0	60	0.0	15	0.0	--	--
	500	1	315	0.0	280	0.0	160	0.0	40	0.0	--	--	--	--